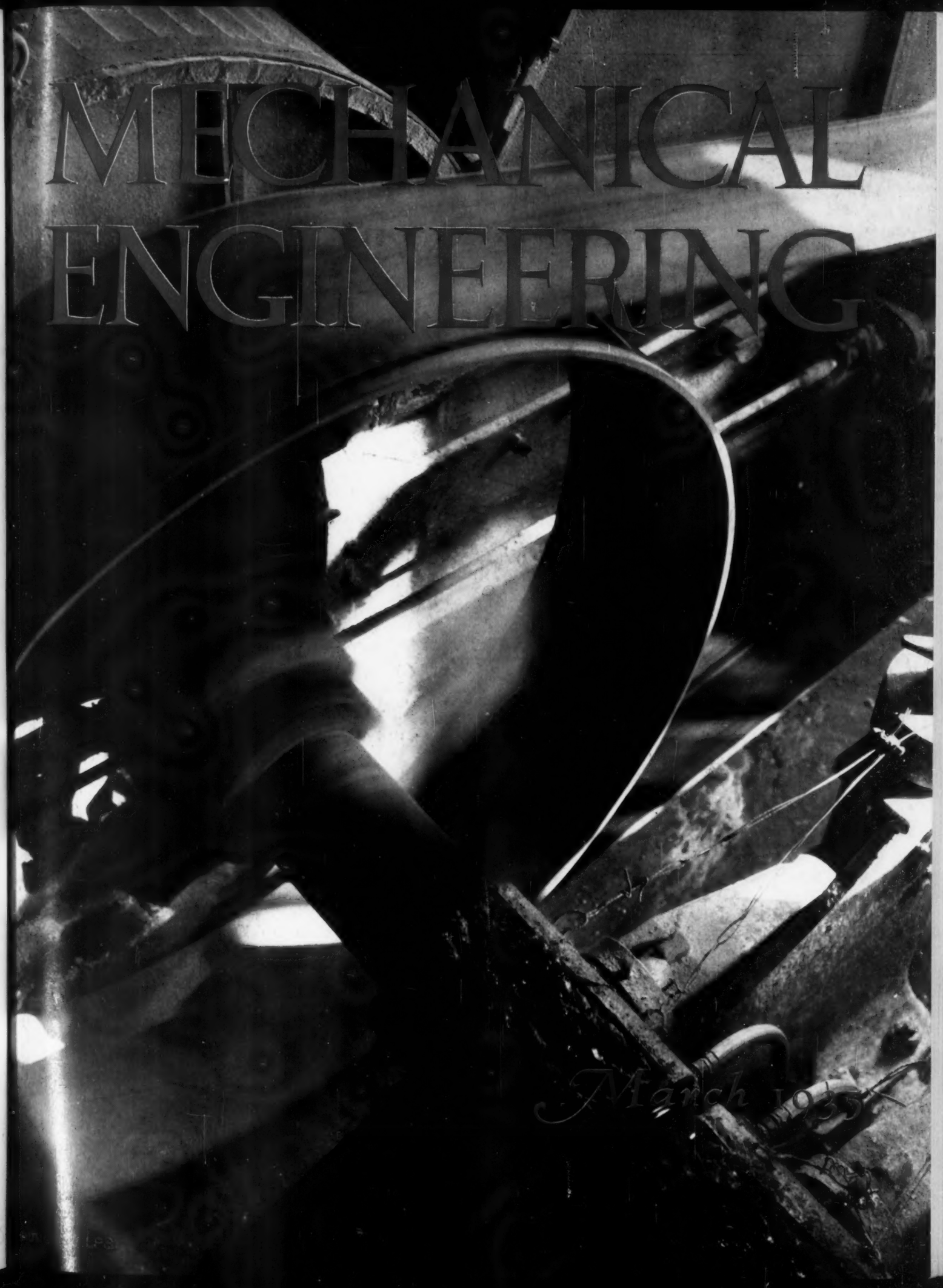
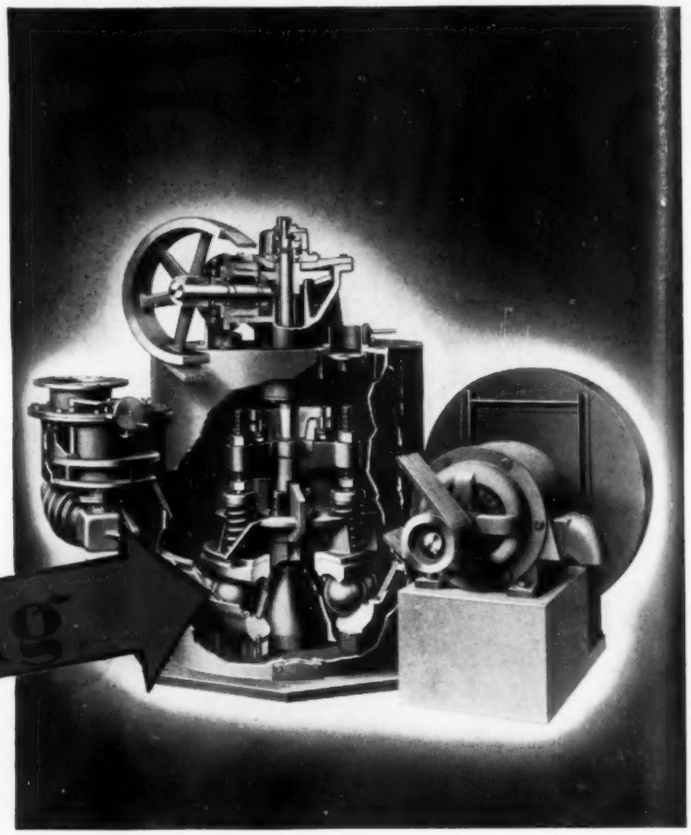

MECHANICAL
ENGINEERING
March 1935

LOWER STEAM COSTS

assured by

the ball bearing grinding principle



Above . . . the B&W Type B Pulverizer with integral feeder and blower . . . one that offers the average industrial plant the full advantages of pulverized-coal firing by making available capacities as low as 500 lb. of coal per hour. Other sizes of Babcock & Wilcox Pulverizers have capacities as high as 50 tons per hour.

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Another contributing factor to the low cost of operation of this pulverizer is its ease of operation, evident in the absence of lubrication worries, in the simple, positive control over fineness, and in its quick response to load changes.

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MECHANICAL ENGINEERING

Published by The American Society of Mechanical Engineers

VOLUME 57 NUMBER 3

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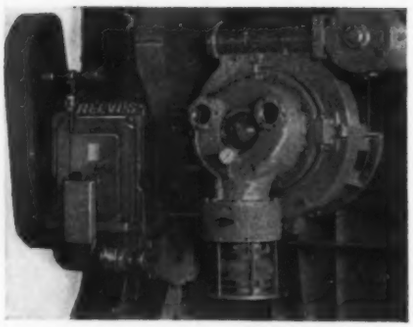
Published monthly by The American Society of Mechanical Engineers. Publication office at 20th and Northampton Streets, Easton, Pa. Editorial and Advertising departments at the headquarters of the Society, 29 West Thirty-Ninth Street, New York, N. Y. Cable address, "Dynamic," New York. Price 60 cents a copy, $5.00 a year; to members and affiliates, 50 cents a copy, $4.00 a year. Postage to Canada, 75 cents additional, to foreign countries, $1.50 additional. Changes of address must be received at Society headquarters two weeks before they are to be effective on the mailing list. Please send old as well as new address. . . . By-Law: The Society shall not be responsible for statements or opinions advanced in papers or . . . . printed in its publications (B2, Par. 3). . . . Entered as second-class matter at the Post Office at Easton, Pa., under the Act of March 3, 1879. . . . Acceptance for mailing at special rate of postage provided for in section 1103, Act of October 3, 1917, authorized on January 17, 1921. . . . Copyrighted, 1935, by The American Society of Mechanical Engineers.

What's New
IN VARIABLE SPEED APPLICATIONS



VACUUM FILTERS

A manufacturer of vacuum filters for use in paper and pulp mills incorporates the REEVES Variable Speed Transmission as standard equipment.

Pictured here is application on filter for save-all work. Through infinite speed adjustability provided by the REEVES, uniformly high recovery of solids—90% to 95% and more—is accomplished; and the recovered stock is delivered at any desired density.

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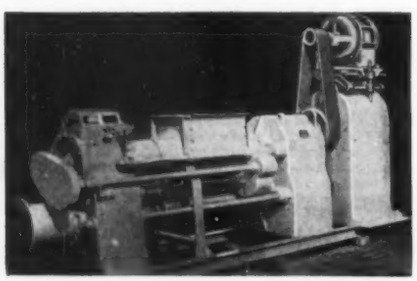

This regulation provides the proper rate of feed for clays of different composition and for different types of ware being processed. Application shown is that of a REEVES vertical enclosed design with individual motor drive.

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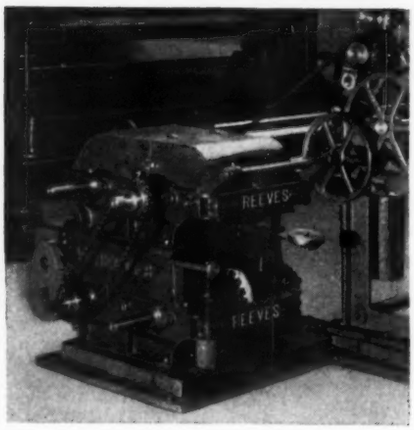

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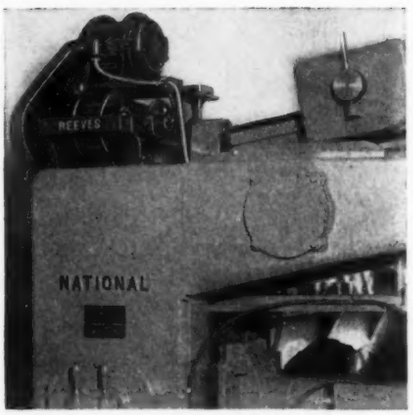

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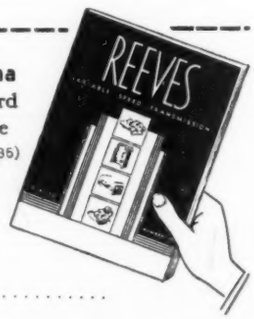


VOLUME 57
No. 3

MECHANICAL ENGINEERING

MARCH
1935

GEORGE A. STETSON, *Editor*

Our Authors

WHO writes for MECHANICAL ENGINEERING? A variety of persons, to be sure. This month a research chemist, the president of an electric power company, a recent technical-school graduate, a museum curator, two groups of physical chemists, a designer of turbines, an expert on the mechanics of rubber, an instructor in engineering mechanics, an authority on the mechanical problems of public health. Next month it will be another and quite as varied a list.

So that readers may know with what authority our articles are written, brief sketches of the authors are prepared for every issue and will be found in the last few text pages under the title "This Month's Authors." It is a good plan to get into the habit of turning to this section and reading about the authors. Without them there would be no magazine.

Jobs for Themselves

ANY ONE who thinks that the young engineers of the country are going to take the present lack of remunerative employment lying down without doing something about it is due for a surprise. For they are not. Turn to the last few text pages of this issue and read the report of the Junior Group of the Metropolitan Section of The American Society of Mechanical Engineers.

These young men are out for jobs and they mean business. They are facing the facts realistically. Perhaps their older brothers and cousins were in a position to pick and choose jobs in the great industries that depend on engineering for design, operation, management, sales, and development. Today's youth looks toward these former opportunities and sees the industries that provided them overcrowded, laying off their men, and the worst hit of all groups. It looks to the consumer-goods field and sees less economic disturbance and few if any engineers employed. Why not develop this field? And that is just what they propose to do. Our guess is that, in spite of opposition and some disappointment, these young men will demonstrate that an engineering training can be applied in almost any business, and with profit. It is foolish to be pessimistic about the future of engineering when such splendid pioneering spirit is still alive.

"What's Going On"

UNDER the general title "What's Going On" there is published every month a miscellaneous assortment of news items and reports that are of importance to readers of MECHANICAL ENGINEERING. This department will be found in the concluding pages of every issue. Because a sense of thrift has convinced us that these items, generally brief and hence not likely to require long periods of reading, may be set in smaller type than is used in other pages, it should not be inferred that the department is considered unimportant. On the contrary, it may be of great importance, and should most surely have the regular attention of all readers.

On these pages readers will find the news of The American Society of Mechanical Engineers, and to these pages they should look for actions of the Society's Executive Committee and its Council, notices of coming meetings, reports on the work of the Society's committees that may be briefly presented, appointments, candidates for membership, recent deaths, and the activities of joint undertakings, such as the United Engineering Trustees, Inc., the Engineering Foundation, the American Engineering Council, The Engineering Societies Library, the Engineering Societies Employment Service, and the Engineers' Council for Professional Development. Readers of MECHANICAL ENGINEERING who wish to keep abreast of any or all of these matters are urged to give close attention to "What's Going On" as an easy and practical way of securing this knowledge.

Growing Interest in History

UNFORTUNATELY, crowded curricula of engineering schools leave little time for the study of history or for the interpretation of the effects of technology on history. Many of us stumble through life without the light which such study might cast upon our way, lacking the perspective and intelligent interpretation that it might give, ignorant, even, of the humble but logical beginnings from which our familiar practices and machinery have sprung. It is encouraging, therefore, and significant of an increasing appreciation of the value of the history that a movement within The American Society of Mechanical Engineers for the study of engineering history is gathering headway.

Authorized by action of the Council at the meeting

in December as a result of a resolution prepared following the reading of a paper which will be found elsewhere in this issue, a committee met recently and discovered sufficient reason and enthusiasm to develop the suggestion that a group to study the history of engineering in this country be established. It is hoped that this group will be representative of all the engineering societies and that it will give serious thought to recording the more recent developments, data for which may still be obtained from the men taking part in them. Thus, before time dims our knowledge of these events, they may be placed upon permanent record for the use of this and future generations of engineers. It is expected that response to the movement will be spontaneous and widespread. Write in if you are interested.

Henry deB. Parsons

REFLECTING upon the events and utterances of the past months during which time so much has been said about a unified engineering profession and about the definition of the term "engineer," it is well to recall that certain individuals have, in their practice and interests, typified the spirit of that unity, and by their lives given a superlative meaning to that name. It is a far cry from absurd restrictions implied in the 150 varieties of engineers found in the New York telephone directory to the simple dignity of the unqualified term as applied to the more noble persons who are really engineers. And there is a wide gap between the minimum requirements set by the proposed ECPD definition, commendable as it is as a first hurdle, and the distinguished attainments in many and usually untouched fields in which that able and perhaps dwindling group of consulting engineers, typified by Henry deB. Parsons, recently deceased, pioneers and practices.

Henry deB. Parsons represented engineering at its best. He embodied those qualities that guardians of the profession's ideals would like to see in ample measure in all who are admitted to its ranks. An inspiring teacher who served on the faculty of the oldest engineering school in this country, recently bereaved of its Director, and of its distinguished alumnus William H. Burr, he remained throughout his life a student, having underway at the time of his death certain researches in soils that pertained to one of the specialties of his practice, foundations. Son of a distinguished family for generations rooted in New York, brother of a pioneer subway builder, he added a luster of his own to his heritage. To him the profession he served had more than ordinary significance. He held its members in respect and affection, and to its organized activities—the engineering societies—he gave liberally, at times of his experience in the technical papers he wrote, at times of his able advice and services, at times of his money. His warm sympathies were deeply touched by the plight of hundreds of brother engineers who suffered from the depression, and though not robust in health himself, he found time actively to aid in the organized relief of the Professional Engineers' Committee on Unemployment. To it he contributed liberally. The appeal to buy bonds of The American Society of Mechanical Engineers found him responsive. The United Engineering Trustees, Inc., he remembered in his will. Thus in many and varied ways he identified himself with his profession.

The world will lose much of sanity, balance, culture, and combined financial and engineering wisdom if it orders the opportunities and ideals it holds out for engineers so that men of the type of Henry Parsons are not attracted to it. In thinking of professional unity and of what we mean by the term engineer, therefore, let us have before us the example of such a man.

The First Hundred Years

IF Mayor LaGuardia, of New York, is successful in carrying out the purpose stated in his letter to Mr. Floyd Carlisle to eliminate, by reason of a low electric rate, "the unsanitary and unsightly gas plants so costly of operation in the very heart of residential districts.... and write off a large amount of obsolete property," the gas companies will literally discover that the first hundred years are the hardest—and the best.

In January, in commenting on the useful career of Frank Sprague, we called attention to the fact that at least one phase of the electric-traction industry had been run in the lifetime of the individual customarily credited with being its founder. This striking example of obsolescence is one which engineers and investors may well consider soberly. In the case of the threat implied by New York's mayor to supplant the use of gas by the use of electricity there is involved the forced retirement by other than technological factors of an extensive industry in which much capital is invested and much equipment is giving useful and satisfactory service.

Outsiders, perhaps, may be permitted the luxury of speculating on the ultimate effects of such a transformation from gas to electricity, assuming that it could or would be carried out, and of suggesting that the Mayor has not by any means exhausted the possibilities of this acceleration of change by a combination of technological and political actions. Led by bold experimenters with fertile imaginations and sometimes little else at stake, the country seems to be in a state of constant agitation over those who, on the one hand, do their best to prod us out of the easy lethargy of the status quo and those who on the other hand take alarm at the perplexing problems set up by this rapid change and urge moratoria on scientific advance.

It is, of course, unnecessary to stop at the elimination of unsanitary and unsightly plants. The beneficences of electricity could, at a price, eliminate every domestic heating plant burning fuel of any kind, and thereby rid us not only of the exhaust gases from those plants, but of their soot, ash, and smoke problems as well, to say nothing of the traffic in fuel and its wastes. And gas brings to mind those noxious fumes which the exhausts of motor cars release to the atmosphere of our streets.

Why not electricity on the automobile? Only a few weeks ago, in answer to a question put to him at a luncheon in New York, Mr. Charles Kettering, who should know something about the subject, admitted that there might exist the possibility of developing an electric storage battery in which a greatly more favorable ratio of energy absorption to weight would be achieved. With such a device the dreams of early experimenters in electric automobiles might be realized, to the doom of the internal-combustion engine. Thus, crowned undisputed king in urban economy, electricity could also more safely reign in rural areas.

Well, well, well! Here in twenty minutes we have noted the passing of the gas industry, the domestic-heater industry, and those contributing to them. We have chilled the "hot oil" of Texas by cutting off its market and have forced the automobile industry into the electrical business. And we have, perhaps, offered some justification for the hundreds of hydroelectric developments proposed by the planners.

But the worst is to follow. Suppose the king himself is forced to abdicate? If the gas industry can be forced out in a century, shall the electrical industry, already half as old, survive the advance of scientific progress and political attack for as long a time? He would be incautious who would give a positive "yes" or "no" to such a question. And in the absence of a positive and accurate forecast, it will pay all engineers and investors to think soberly about the elements in our national life—technological, social, economic, and political—which may affect so profoundly the apparently basic industries in which our interests lie. Our plea is for a spirit of awareness to the possibilities of change and for preparation to meet it intelligently. The correspondence between Mayor LaGuardia and Mr. Carlisle merely supplies the opportunity to urge this point of view.

Machinery Is Inevitable

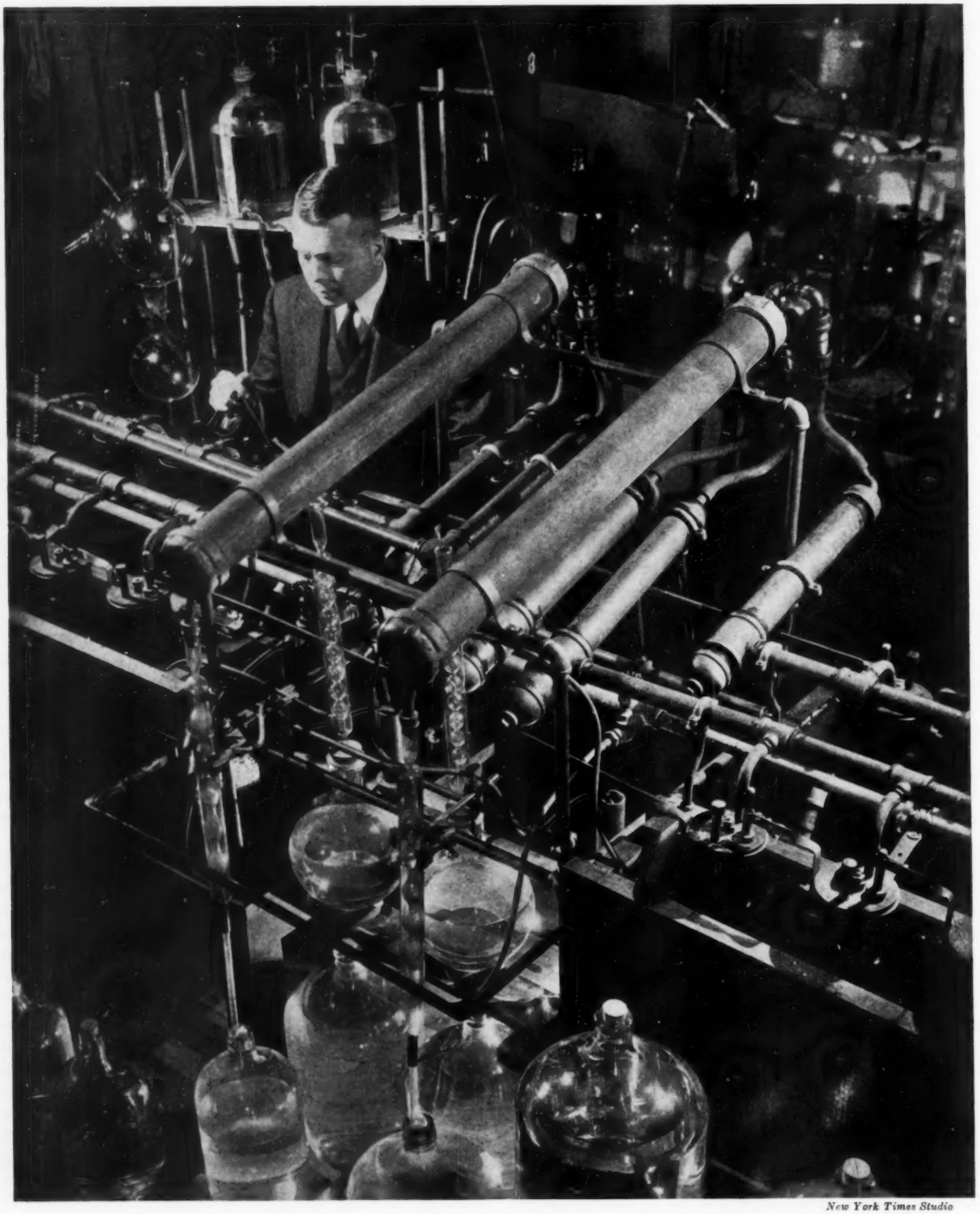
MUCH comment has been made on the report of the NRA Research and Planning Division on conditions in the automobile industry. It has been stated that the report paints a "dark picture" of human relations and the treatment of employees. But of especial interest to engineers is the attention said to have been directed to the extraordinary progress of new devices introduced during depression years, by means of which large numbers of workers have been displaced.

The report itself we have not read, but the newspaper accounts of it and the comment it has stirred up indicate that the technocratic ghost is stalking once more. In so far as this report and the impression it creates raise doubts in the minds of readers as to the value of the services which the inventiveness and managerial skill of engineers have rendered, and sets up hazards—already great in the depressed durable-goods industries—for the further development of engineering, engineers have a right to be concerned and to counteract these influences as vigorously as possible. In so far as the report and other documents and arguments exerting similar influences create the impression that in some manner we can and should stem the flood of machinery that increases our productiveness, the question is one for philosophers and economists to debate, and the engineer's interest is in common with that of all civilized men.

Dean Kimball has called attention on several occasions to the fear expressed by Malthus about a century ago that rates of increase in population and food supply were so out of balance that the human race was likely to face extinction by starvation. Today, however, a glut of foodstuffs is threatening to choke a society convalescent from economic illness. One of the factors that turned scarcity into plenty was this very increase in the efficiency of production that so many persons are worrying about. Restrictions in output, restrictions in new plant capacity, restrictions in hours of production and hours of work, to say nothing of destruction of stocks, have been resorted to in order than men might somehow have more by producing less. And yet the tide of human progress is in the reverse direction.

Only a dogmatist or a shallow thinker would attempt to belittle the very serious problems of employment that the world faces, but to substitute for so-called technological unemployment what might be termed untechnological employment is no answer to those who wish to see the general level of the standard of living for all raised in distinction to those who, because of certain maladjustments, find no solution except the setting of that level on a progressively lower and broader base. A man who persists in spending his time in trying to develop a machine that will operate counter to the principle of the conservation of energy may hold high ideals for the good of mankind but he is not likely to succeed in bringing about the benefits of abundant power. On the other hand an engineer with a knowledge of this principle and the limitations it imposes upon him as a designer can be very successful in producing a considerable amount of power with a surprisingly high efficiency. It would appear that progress in human affairs will be not only more rapid but less disturbing to individuals and social groups if some of the forces that seem to be at work in the world are frankly recognized and made to yield a maximum of benefit. If labor, for example, would accept increased machinery as inevitable and beneficial to it and make use of this fact as a constructive principle in its fight for higher wages and better working and living conditions, it would find itself going with the current rather than against it.

What we need is not more reports calling attention to the natural growth of technology and efficiency in production, but more and better ways of employing people in productive capacities, creating more wealth, and raising the standard of living. Give engineers half a chance and they will provide the efficient production and management. Give them practical encouragement and they will bring forth the new things and services that future generations will find satisfying and desirable. The people themselves will have to decide how to make use of this greater productiveness.



New York Times Studio

Prof. Harold C. Urey, Who Received the Nobel Prize for His Work on Heavy Hydrogen and Heavy Water, in His Laboratory

HEAVY HYDROGEN *and* HEAVY WATER

By G. M. MURPHY

COLUMBIA UNIVERSITY

THE discovery of heavy hydrogen and the subsequent preparation of considerable quantities of heavy water have caused some excitement in scientific circles. The purpose of this article is to explain the discovery and to indicate its significance for readers of MECHANICAL ENGINEERING.

The scientist has been interested in the structure of matter since the days of the Greek philosophers, or perhaps even earlier. Our modern ideas are based on an atomic model proposed in 1911 by Lord Rutherford. According to this model, the atom consists of a heavy nucleus, surrounded by a cloud of electrons. Most of the chemical properties of an element depend on the number and arrangement of the electrons, and the present theory of this part of the atom, which is called "quantum mechanics," seems adequate for explaining the experimental data. But for the nucleus, there is no suitable theory available, and it is for this reason that a large part of research in atomic structure today is concerned with the study of the nucleus.

For some years it was generally believed that the nuclei of any one element are all identical. But with the discovery of radioactivity it soon became apparent that this was not true. In 1912 it was shown that a non-radioactive element, neon, also contained more than one kind of nucleus. They differed only in mass, the chemical properties being nearly identical. These are called "isotopes" because they occupy the same place in the periodic table of the elements. Since that time it has been found that most atomic nuclei are composed of two or more isotopes.

An isotope of hydrogen would be particularly interesting because its mass would be twice that of the ordinary hydrogen atom and its nucleus would be the simplest particle except for the hydrogen nucleus, the proton. There was some evidence for the existence of a double-weight hydrogen and it had been predicted that its abundance relative to ordinary hydrogen would be one part in 5000.

PROFESSOR UREY'S RESEARCHES IN HEAVY HYDROGEN

Professor Urey set out to make a search for heavy hydrogen, but because of its rarity, he knew that detection would be difficult if not impossible. A method of concentration was needed and a fractional distillation process seemed promising. Professor Urey and the author made some calculations which showed us that fractional distillation of liquid hydrogen at —435 F should concentrate the heavy hydrogen if it existed. Since liquid hydrogen was not available to us at Columbia University, we asked Dr. F. G. Brickwedde, of the Bureau of Standards in Washington, to collaborate with us. He allowed about two gallons of liquid hydrogen to boil away until only a few drops were left. These were then evaporated and the gas collected in a glass bulb which was shipped to us in New York where we prepared to examine this specially prepared sample of hydrogen.

Our method of detection was spectroscopic. If hydrogen gas is put into a tube equipped with electrodes and then a potential of several thousand volts is applied, the gas becomes luminous in a similar way to neon advertising signs. If the light is then examined by means of a spectrograph, a series of spectral lines is obtained, and in the case of hydrogen, a theory had been developed by Prof. Niels Bohr. From this theory, we could calculate that each hydrogen line should be accompanied by a faint satellite if any heavier isotopes existed. Moreover, we could calculate exactly how far from the hydrogen lines these satellites should appear, and if all the calculations were correct, they should be one-hundredth as intense as the light hydrogen lines. This indeed proved to be the case, indicating that the isotope of mass two did exist and in approximately the amount required by the theory. An attempt to detect still heavier isotopes of hydrogen at this time was unsuccessful, but one of mass three has since been found. This is present to the amazingly small amount of one part in one billion of ordinary hydrogen.

METHODS OF PREPARING HEAVY HYDROGEN

The method of distilling liquid hydrogen would be a tedious and expensive process for preparing large quantities of heavy hydrogen, and it is doubtful if the discovery would have been as useful without better ways of concentration. One was discovered almost immediately by the late Dr. E. W. Washburn, of the Bureau of Standards. If an electric current is passed through a caustic-soda solution, hydrogen and oxygen gases are liberated at the electrodes. This is one of the commercial methods of preparing these two gases. Dr. Washburn believed that light hydrogen should be evolved more readily than the heavy variety and that if the electrolysis were continued for a long time, the unelectrolyzed water remaining in the cells would be composed of almost all heavy water. This proved to be true, and several investigators, notably Prof. G. N. Lewis, of the University of California, have prepared very pure samples of heavy water in this way.

NAMING THE NEW PARTICLES

The naming of new particles has become a great sport during recent years with the discovery of the cosmic ray, the neutron, the positron, and so on. A name seemed necessary for the heavy hydrogen, and it was christened by the three discoverers "deuterium" from the Greek stem "deuteros" meaning second. The nucleus of the atom is called the "deuteron," although the erroneous word "deuton" is often used. The chemical symbol is D, and so heavy water is D_2O. Samples of water containing less than 100 per cent of deuterium will also contain the molecules H_2O and HDO.

THE PROPERTIES OF HEAVY WATER

In addition to the difference in vapor pressure, which was used in the first separation, other slight differences in physical properties have been observed. Table 1 contains a few of the more important constants for ordinary and heavy water.

TABLE 1

	H_2O	D_2O
Freezing point, C.....	0.0	3.8
Boiling point, C.....	100.00	101.40
Density.....	1.0000	1.1079

The wide application of deuterium and deuterium oxide or heavy water to scientific research is well illustrated by the fact

that more than 400 papers concerning it have appeared in scientific journals since its discovery in 1931. These papers are concerned mostly with chemistry, physics, and biology. Only a brief indication as to its value in these fields can be given here, but for more complete details, the reader is referred to a paper entitled "Significance of the Hydrogen Isotopes," by H. C. Urey, which appeared in *Industrial and Engineering Chemistry*, Vol. 26, 1934, page 803. The chemist has a useful tool for testing some of his theories, for he may investigate the effect of mass on his chemical reactions. With heavy water, some reactions are slowed down while others are speeded up. The physicist has a new particle which he may play with, and he has found it very useful in nuclear transmutations. The biologist has investigated the effect of heavy water on the growth of certain living organisms. In some cases the animals die, while in others they seem to thrive, especially in low concentrations of heavy water.

GREATER SUPPLIES OF HEAVY WATER NEEDED FOR EXPERIMENTAL PURPOSES

One of the great needs at present is an adequate supply of heavy water for scientific researches. There is at present, commercially available in this country, heavy water of all concentrations in very limited amounts. This is obtained as a by-product in electrolytic hydrogen plants. The operation consists in electrolyzing a certain volume of water to the smallest possible residue. The hydrogen evolved can be collected in the usual way and sold so that the preparation of heavy water does not disrupt the usual routine of the plant to any extent.

The process is rather slow, however, and during the later stages of the operations it must be carefully handled, since the water must be protected from the moisture in the air, heavy water being very hygroscopic. The present price is 20 dollars per gram, but the demand far exceeds the available supply. It is reported that it may be obtained in Norway where electric power is cheap for about one-tenth this price, but the main difficulty at present seems to be in obtaining suitable amounts rather than the price. Some experiments are being performed with the hope that fractional distillation of liquid water may be used for obtaining heavy water which if successful should result in larger amounts becoming available.

ENGINEERING AND INDUSTRIAL USES OF HEAVY WATER UNDEVELOPED

As far as engineering uses are concerned, little can be said at present. From Table 1, it can be seen that the fundamental constants which would interest the engineer remain practically unchanged, except for the most precise work. For instance, the usual standard of density is taken as the weight of one cubic centimeter of water. Samples of water taken from various sources show a variation in density due to different concentrations of heavy water of as much as several hundred parts per million. If water is taken from an old electrolytic cell or a storage battery that has been in use for some years, it will show an increase in density of considerably more than this. But obviously these slight differences are of no interest to the engineer, since he does not usually measure densities to parts per million.

As far as industrial uses are concerned, there are none at present and there seems no immediate chance of any commercial application. One must not be too hasty in drawing such conclusions, however, for it is extremely improbable that any commercial uses were foreseen for the rare gases of the atmosphere at the time of their discovery. The most abundant of these is argon, which comprises only 0.94 per cent of the atmosphere by volume. It is estimated that the use of argon in electric-light bulbs, rather than nitrogen as formerly, saves the United States 125 million dollars yearly on the lighting bill. The substitution of a mixture of krypton and xenon would decrease the present bill by another 200 million dollars annually. Yet these two gases are exceedingly rare, krypton occurring to the extent of only one part in a million, and xenon, one part in 11 million, parts of air. For helium, there is only 1 lb in 725 tons of air, which is much less abundant than heavy water of which there is 1 lb in about 2.5 tons of water. It would therefore seem very unwise to predict that heavy water or heavy hydrogen will not find industrial uses, but this is a question that must be reserved for the future.

Engineering Centenaries in 1935

AMONG the centenaries of this year will be that of the versatile Robert Hooke, born three hundred years ago. Every engineer is familiar with Hooke's law, but probably few are acquainted with the range and diversity of his experimental inquiries. He was one of the outstanding contemporaries of Newton, Wren, and Boyle. Two hundred years ago, Jesse Ramsden, the famous instrument maker, was born at Halifax. British instrument makers of the eighteenth century contributed largely to the advancement of practical astronomy and geodesy, and Ramsden's three-foot theodolite preserved in the Science Museum is well worth examination. Scarcely less famous was Edward Troughton, another great instrument maker, who died in 1934, while that year also saw the death of Captain Henry Kater, who was one of the first who worked on the trigonometrical survey of India, and who afterward became well known for his accurate pendulum experiments, and his knowledge of weights and measures. These men were both theorists and practicians, but Sir Edward Banks, who died in 1835, was all his life employed in practical construction. From canals and roads and buildings, he turned his attention to works of greater magnitude, and he will always be remembered as the contractor, with his partner John William Joliffe, for the building of Waterloo, Southwark, and London Bridges, and Sheerness Dockyard.

Of the various engineers and inventors born a century ago, none bore a more honored name than Bryan Donkin (1835–1902). Donkin [a member, A.S.M.E.] was much influenced by Hirn, and few know more about steam engines and gas engines. One of his works was the translation of Diesel's "Theory and Construction of a Rational Heat Motor." Of Donkin's contemporaries, Jeremiah Head (1835–1899) was president of the Institution of Mechanical Engineers; Lord Airedale (1835–1911) was both president and Bessemer Medalist of the Iron and Steel Institute, while John Jones (1835–1877) was the virtual founder of that Institution. There are other names which could be added to the list, but, in conclusion, we may mention the two American inventors, Samuel Johnston (1835–1911), who made many improvements in agricultural machinery, and Elisha Gray (1835–1901), who, starting life as a carpenter, became a professor at Oberlin College, and then distinguished himself as a maker of electrical appliances. Gray missed by a few hours being the first to patent the telephone. His visit to the American Patent Office, on February 14, 1876, was made the same day that Alexander Graham Bell lodged his claim for a patent. Gray had upward of sixty patents to his credit, and his abilities were recognized by his being chosen as Chairman of the International Congress of Electricians at the World's Fair at Chicago, in 1893.—*Engineering*, Jan. 4, 1935, p. 17.

Chicago Architectural Photographing Co.

OPPORTUNITIES FOR YOUTH TO LEARN ABOUT ENGINEERING AND TECHNOLOGY ARE PROVIDED BY THE MUSEUM OF SCIENCE AND INDUSTRY AT CHICAGO

The STUDY *of* TECHNICAL HISTORY

A Plea for an Organization in This Country Devoted to the Study of Engineering History

By I. N. LIPHSHITZ

BROOKLYN, N. Y.

IN THE last few years there has been a decided interest shown by the general public and by groups of specialists in the problems and developments in science and engineering. Philosophers, economists, journalists, as well as scientists and engineers have taken it upon themselves to explain these fields to the public, in many cases to trace their growth and development, in some cases to analyze their place in society, in history. At times these explanations have been fairly clear and correct, more often they have been tinged with a desire to convey awe and mystery to the growth of these subjects. Too often this latter most undesirable approach has been due to a lack of knowledge on the part of the individual authors of the particular fields which they were studying. In some instances, perhaps, there was insufficient factual material; in others material was present but not collected and correlated.

Just as, however, these post-war years have given rise to so much study in the fields of history and social criticism in general, so they have given rise to the study of many particular fields, among them the history of those important basic fields of social culture—engineering and science.

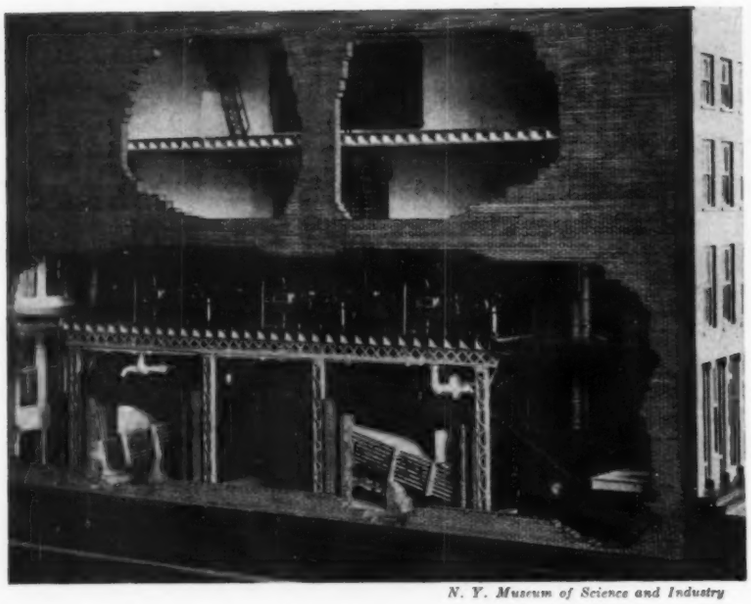
Institutions have arisen throughout the world to study the history of these subjects and to present a knowledge of their history and development to the layman. There arose on a large scale the museums of science and industry and together with them bodies for the organized study of technical history.

America, however, lagged far behind in the establishment of such institutions. The industrial-museum movement developed here quite late. Only within the last few years has the movement expanded here to any great extent. For in this short time, two museums of science and industry, the fruits of long and difficult periods of planning and research, built under severe financial hardships, at last opened their doors. On the first of January, 1934, the Benjamin Franklin Memorial and Franklin Institute Museum in Philadelphia was opened to the public. Only six months earlier Chicago's citizens saw the opening of the Rosenwald Museum of Science and Industry. Previously there had existed only the small industrial museum in New York City, the industrial collections of the Smithsonian Institution in Washington, and the antiquarian museum of Henry Ford at Dearborn.

An organized body for the study of the history of technology has yet to be formed in this country. There exist no institutions in this country corresponding to the Newcomen Society of England, the historical division of the Verein deutscher Ingenieure, or the Osterreichisches Forschungsinstitut für Geschichte der Technik, with their technical-historical publications and transactions.

We can, however, see definite trends toward the study of technical history in the American engineering societies. Periodically there have appeared excellent historical treatments in

Presented at the Annual Meeting, New York, N. Y., December 3–7, 1934, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS.



N. Y. Museum of Science and Industry

MODEL OF THE FAMOUS PEARL STREET ELECTRIC LIGHTING STATION, NEW YORK, MAKER OF HISTORY IN THE ELECTRICAL INDUSTRY

the society journals by individual members of the societies. Biographies of prominent engineers have been written. (The American Society of Mechanical Engineers, for example, started a series of biographical studies more than twenty years ago.) Furthermore, the American engineers who hold membership in the Newcomen Society have formed a branch in this country and hold annual meetings.

The Business Historical Society, an organization primarily interested in the collection and study of economic and business records and documents, and at present located in the Baker Library at Harvard University, has done some valuable work in the field of technical history. The History of Science Society has occasionally done some work in this field.

Small societies such as the Railway and Locomotive Historical Society, and the Early American Industries Association have been formed and indicate the interest that is rapidly growing. Special library collections on the history of technology are being gathered. Industrial archives are being preserved, and there are other manifestations of this growing interest.

Let us examine some of the early efforts toward the study of technical history in this country. The economists and historians have treated to some extent the development of industry and manufactures. They treat this material rather broadly. Great periods are covered, general trends are noted. The actual technology of the period, namely, the equipment, the tools, the instruments, are only sketchily covered if at all; factory and industrial organization is somewhat better presented. These works are economic histories, hardly the history of technics.

As H. W. Farnam states in the introduction to V. S. Clark's excellent pioneer work on the "History of Manufactures in the United States:"

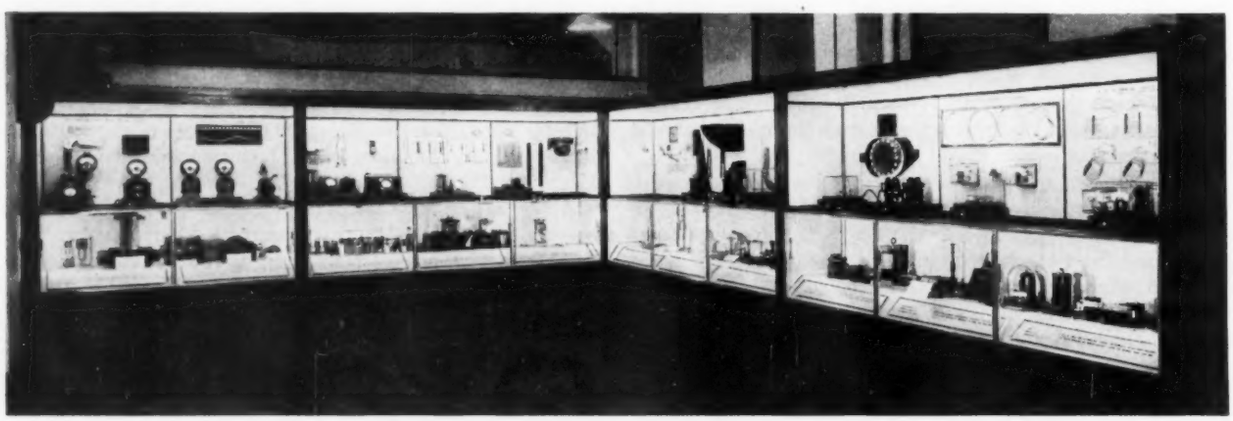
> It (this book) is an economic history in the strict sense of the word. It does not deal with technology and mechanics; it does not give biographies of prominent manufacturers; it cannot cover the details found in histories of specific industries. It does, however, give an interpretation in broad outlines of the development, the organization, and the economic interactions of the manufacturing industry in our country from its feeble beginnings three centuries ago down to its truly remarkable expansion of recent years.

This treatment is characteristic of almost all economic histories. The economic historians were greatly handicapped in their work by the lack of technical histories and organized industrial archives. Their works are, however, in many cases important contributions to the field and are of great value to the technical historian.

In the history of engineering proper we have had such works as J. W. Roe's "English and American Tool Builders," A. P. Usher's "History of Mechanical Inventions," Kirby and Laurson's "The Early Years of Modern Civil Engineering," R. H. Thurston's "History of the Growth of the Steam Engine," and several others. Such works in our country have been few and far between. Even biographies of prominent engineers, mechanics, and industrial leaders or histories of individual industries have been few.

It seems that the only time America became aware of its engineering history was at the various anniversaries such as engineering society anniversaries, industrial anniversaries, birthdays, "Centuries of Progress," etc. As is usually the case on such occasions, the studies are marked by a wave of panegyrics and are generally quite shallow and uncritical.

American engineering history is indeed in need of analysis and interpretation. Especially with the growth of the industrial-

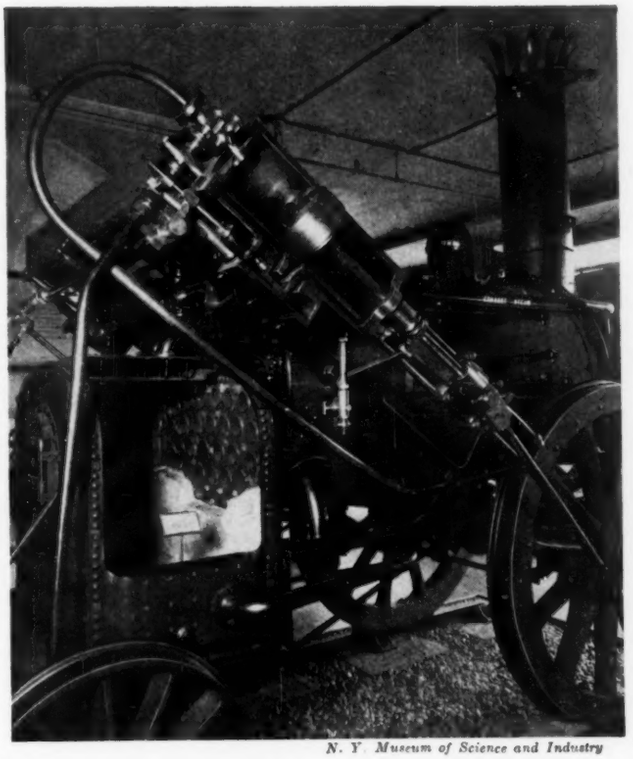


A PORTION OF THE EXHIBITS OF ELECTRICAL SCIENCE AND TECHNOLOGY, NEW YORK MUSEUM OF SCIENCE AND INDUSTRY

museum movement and the greater interest shown by the public in the history of engineering is this study important. Unless an organized, well-directed unit for this study is formed here, we shall be unable to check the disappearance and destruction of old machines and records, technically important equipment which is of value to the industrial museums, and other materials which are essential for the study and interpretation of technical history. Technically important items are often too close to our times to have their historical value properly recognized, and it will be the duty of both the industrial museum and a technical-historical society to create interest in them.

Besides the collection and preservation of engineering records and equipment, it will be of utmost importance for an organized unit to study and interpret our engineering and industrial history. A mere chronological treatment is not enough. An antiquarian or collector's approach is to be guarded against. We must examine technical developments in the light of their social and economic background. What historical conditions, what social needs aided or caused the technical advances to be made? Why did they occur in a certain place at a certain time? Who is responsible for advances in engineering? It is the duty of the technical historian to analyze and provide answers to such questions as these. For only when we study the history of engineering against the general historical and social background are we able really to understand it, to analyze its various trends and directions, and to explain it properly.

We see, then, some of our tasks and problems in the study of engineering history. How are we to conduct our work? What form shall an organization for this study take? These are questions for discussion among the American engineers interested in this field. From the development of the technical historical movement in the European countries where it originated, and from the problems and organization of these earlier bodies we can indeed learn much. We shall, therefore, now pass to a discussion of this development.



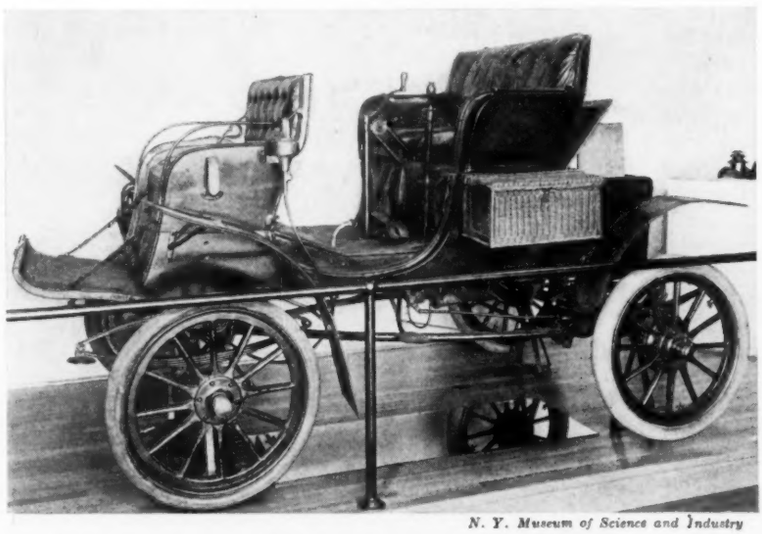
N. Y. Museum of Science and Industry

A LANDMARK IN THE HISTORY OF THE STEAM LOCOMOTIVE—MODEL OF STEPHENSON'S "ROCKET"

THE MOVEMENT IN THE EUROPEAN COUNTRIES

The movement for the organized study of engineering history originated in Germany at the beginning of this century. Here in the Verein deutscher Ingenieure (V.D.I.) and at the initiative of such men as the late Oskar von Miller and Conrad Matschoss, the movement was started and given great impetus. Miller and Matschoss have been actively associated with the history-of-engineering movement from the very beginning up to the present day, Miller as founder and director of the Deutsches Museum, and Matschoss as editor of the "Beiträge zur Geschichte der Technik und Industrie."

The Deutsches Museum was founded in 1903. Having as its aim the presentation of the development of science and engineering, it stimulated many students in the study of engineering history. To the museum staff the study of technical history was a decidedly practical problem, necessary for its work in gathering and arranging its exhibits. Many engineers realizing the importance of this work engaged in it. Soon there were papers on various phases of the history of technology covering many periods. Since the society transactions were not always the place for technical historical papers (they could not offer the space, and in many cases the papers did not have general appeal), the V.D.I. decided in convention at Wiesbaden in 1909 to issue a special volume annually on technical history. The same year the first volume appeared under the title "Beiträge zur Geschichte der Technik und Industrie." It was edited by the able Dr. Conrad Matschoss who edits the Beiträge even today. In it there appeared historical studies of machine development, of the development of various industrial concerns, and biographical studies of mechanics and engineers.

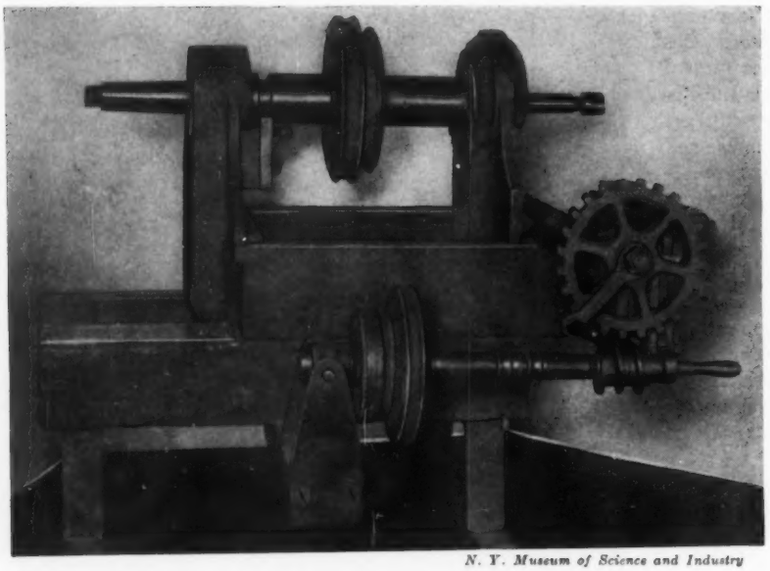


N. Y. Museum of Science and Industry

A STEVENS-DURYEA CAR OF 1903, REPRESENTING A PHASE IN THE DEVELOPMENT OF MODERN TRANSPORTATION

Matschoss very correctly stated in the foreword to this first volume the importance of the engineer in the study of technical history.

"He (the engineer) must write the history of



N. Y. Museum of Science and Industry

THE HISTORY OF THE MILLING BEGINS WITH THIS FIRST OF MILLING MACHINES BUILT BY ELI WHITNEY ABOUT 1818

his art. There is no one who can take this away from him, because only one intimately connected with technics can write the history of technics."

For years Germany continued to build her technical museum and to further her technical historical movement. These have always been the guiding points for similar institutions in other countries. Under the combined impetus of the Deutsches Museum and the Beiträge, interest in technical history was stimulated throughout the country.

Especially important in this respect, beside the exhibits of the Deutsches Museum, were the "Technische Kulturdenkmale." The idea of the preservation of especially important technical items in the original as cultural monuments, just as art monuments are treated, occurred to Dr. von Miller before the World War. The development of this idea was hindered by the outbreak of the war. Later, however, it was taken up and a special group for this work was organized in the museum. The widest cooperation was sought from all interested—the technical societies, the historical societies, and the general public.

Besides these activities, work in the biographical field has been stimulated in Germany. In 1925, when the new building of the Deutsches Museum was opened, there appeared a biographical handbook "Männer der Technik," with sketches of the lives of early engineers, mechanics, industrialists, and other important technical figures. The importance of the study of biography was recognized early, due to the lack of well-organized archives on early engineering history. The publication of personal memoirs of important engineers, especially those who had lived through the rapid period of technical development of the last century, was encouraged, since this would be of considerable use to future technical historians.

In spite of all this excellent foundational work, it was not until 1930 that a special division for the organized study of technical history was formed by the V.D.I. The plans for such a group were discussed at the V.D.I. convention in Vienna on September 19, 1930, where for the first time a special session on technical history took place. Dr. Matschoss reported that the Board of the V.D.I. had decided to found a special division for this study and had set the following tasks for it: The division was to coordinate all organizations working in the field or able to work in the field of technical history. It was to continue in an organized fashion all the historical work which had hitherto been carried on in the V.D.I. This division should by a collection of suitable materials and working forces prepare the way for the writing of a large authoritative work on the history of technology on a sound scientific basis.

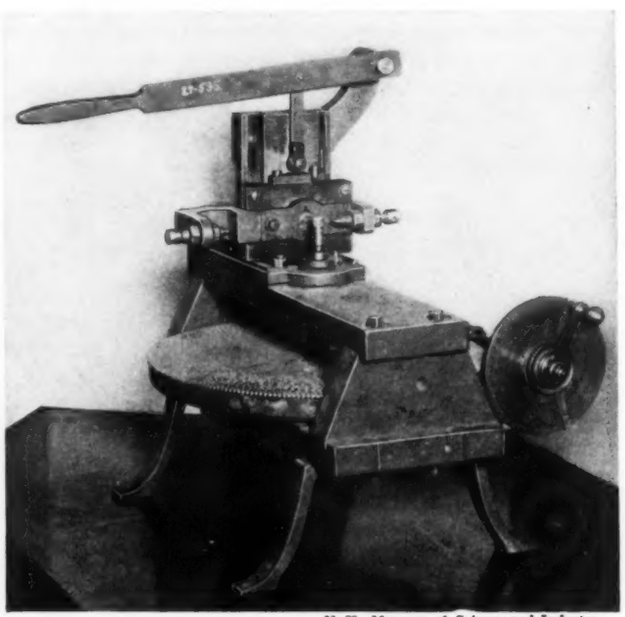
It is indeed significant that in his speech Dr. Matschoss stressed the cultural significance of the history of technics. He stated that the task of the technical historian was not merely to state many details. These were necessary as building stones. The real purpose of this study, he said, was to explain the great connection between technics, economics, and culture.

The special division had its first session at the V.D.I. convention in Köln on June 28, 1931. These last developments were indeed a fitting climax to more than thirty years of research work in the history of technology.

How did the movement fare outside of Germany? To this we pass now.

It was in England that the first organization for the study of technical history was formed. Here in 1920 the Newcomen Society for the Study of the History of Engineering and Technology was organized. The object and tasks of the Society are well stated in its constitution adopted in 1921.

> The object of the Society is to encourage and foster the study of the history of engineering and industrial technology. Stated in greater detail, it is:
>
> (1) To disseminate historical information among its members by meetings, intercourse, discussion, correspondence, circulation of notes and papers, and visits to objects and places of interest.
>
> (2) To act as a channel of communication between members who are engaged on similar lines of research and study; to indicate as far as possible where information is to be found.
>
> (3) To collect and preserve or cause to be preserved, locally or nationally, examples, records, manuscripts, drawings, and illustrations of, or relating to, engineering work and industrial processes.



N. Y. Museum of Science and Industry

AN EARLY INDEXING MILLING MACHINE

(4) To collect and preserve in a similar way biographical matter concerning men who have contributed to engineering or industrial progress.

(5) To publish from time to time a volume containing original papers by members, bibliographical notes, and historical material not generally accessible.

(6) To form by collaboration among its members a card index of published information on the historical aspect of engineering and technology.

(7) To do all such acts as shall lead to active corporate life of the society.

The society has issued a volume of transactions each year since 1920 and has received wide recognition. It participated actively in the second International Congress of the History of Science and Technology held in London from June 29 to July 3, 1931. Many Americans hold membership in the society.

Last to join the existing institutions for the study of technical history was the Osterreichisches Forschungsinstitut für Geschichte der Technik in Wien (Austrian Institute for the Study of the History of Technology) which was organized in July, 1931. This institute is connected with the Technical Museum in Vienna and is supported from much the same sources as is the museum. In 1932 it published its first volume, "Blätter für Geschichte der Technik," edited by L. Erhard. The main purpose of the institute is to be research in the technical history of Austria. Its organization and methods are similar to those of the Newcomen Society.

PROBLEMS OF AN AMERICAN SOCIETY

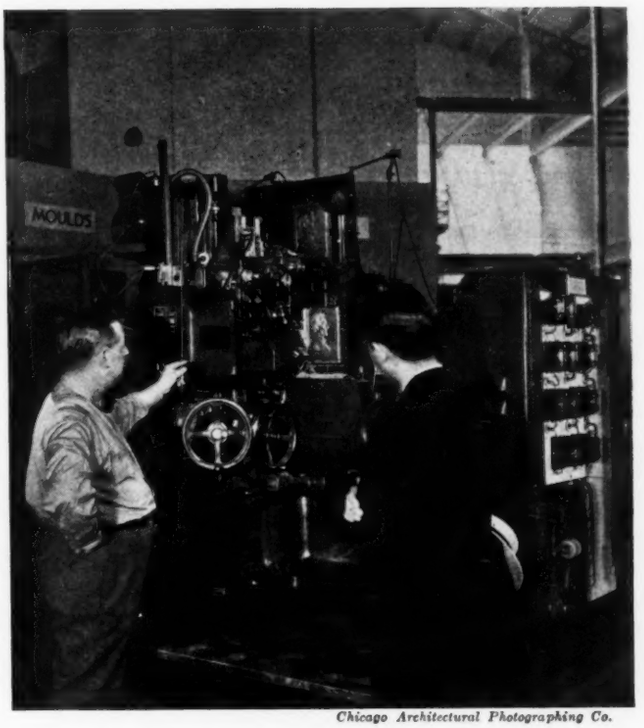
We have seen then the development of the existing societies and their present general structure. We noted their methods of work and discussed them in some detail. From their organization, I believe, we here in America must take our cue. Our general structure should follow along their lines, but the exact structure, functioning, and organizational affiliations are matters to be worked out later in practice.

What are some of our tasks and problems? What shall be the scope of our studies? What are to be our source materials? These are questions which will arise to the individual research student and to the technical historical society as a body.

Of course, the nature of the topic we are covering and the period we are working in will, to a great extent, determine the treatment and the sources. The material available—machinery and technical remains, and documentary material—will be different for different periods. In general, however, we can look to many established institutions for aid. Library and museum collections, industrial archives, business records, state papers, historical society papers, the technical press, the periodical press, memoirs—all are source materials for the technical historian and are available in a greater or lesser degree depending on the period which he is studying. In many cases the materials and documents must first be collected and organized. Many libraries and historical societies have started doing this and can be spurred on in their work by a technical historical organization.

What shall be the scope of the studies of an American society? Shall its work fall wholely in the recording and analysis of American technology? Quite obviously there is no nationalism in technology.

The history of technology cannot be studied by countries separately, for its development is world wide. Technical advances do not appear in one country and stay there. As soon as a technically important development is made, it is adopted in every part of the world in which the industrial structure is sufficiently well advanced to make use of that development. When an industrially backward nation starts upon a period of industrial growth, it does not go over all the steps which the more advanced countries have made, but immediately makes use of everything that technology has developed up to that time. It transplants existing technical equipment and knowledge to its own territories, adapts it to its own peculiar problems, and enlists world-wide aid in its work. This is what has taken place in most of the colonial countries which have recently been industrialized. This is what is taking place in Russia now.



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SHOWING WHAT A MODERN MACHINE WILL DO AT THE MUSEUM OF SCIENCE AND INDUSTRY, CHICAGO

Our own country is indebted for much of its industrial development to foreign inventors, technical influences, and aid. In dealing with the history of American technology we must under no circumstances fail to take into account these influences.

However, it is advisable that we start our work in those branches of technology which have been developed to a great extent in our country and which have come to be looked upon as peculiarly American. Then we can expand our work to include general world development.

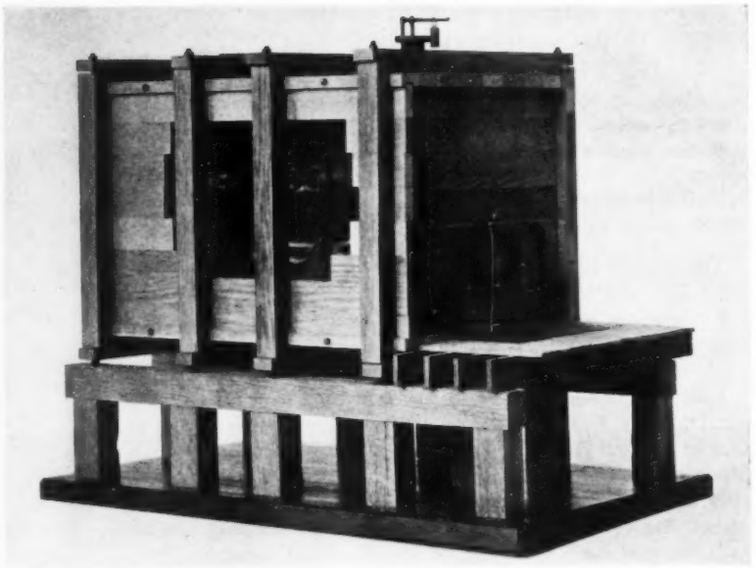
Furthermore, it is important that we work on the industrial growth of the last century, especially the period since the Civil War. Industrial growth during this period has been so rapid that unless we begin to study it immediately, much of what has happened will be lost. It has very often been the case that technical historians have studied the early stages of technical development and have neglected the study of the development of later or "modern" technology. It is important that this period be treated.

From the foregoing discussion, the striking need for an organized, well-directed unit for the study of technical history in America is indeed apparent. The incentive it can offer for study in this field, the aid it can give to our growing industrial museums, the influence which it can exert on the studies of the historical societies, the factual basis which it can build for later critical histories and evaluations—all point to the conclusion that the organization of an institution of this nature should not be long delayed.

WOODEN STEAM BOILERS

By FRANK A. TAYLOR

SMITHSONIAN INSTITUTION, WASHINGTON, D. C.

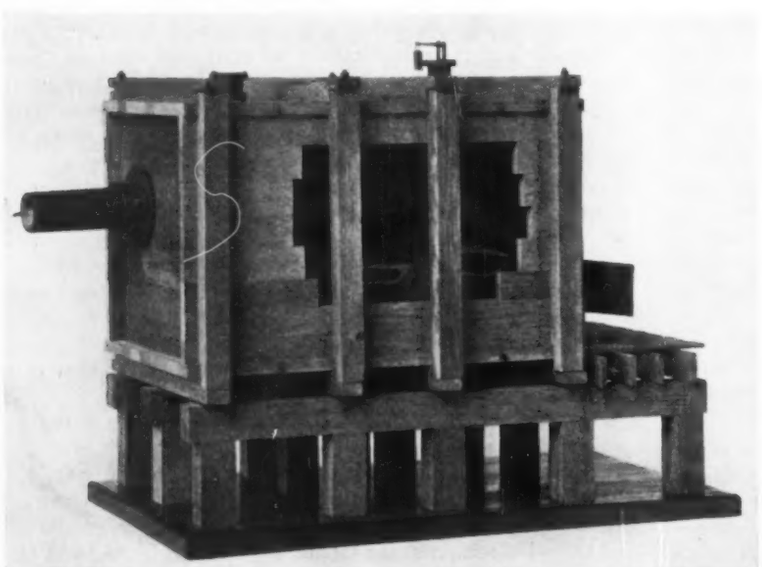


THE ORIGINAL OF THIS WOODEN STEAM BOILER WAS USED AT THE CENTER SQUARE STATION, PHILADELPHIA WATER WORKS, 1801

THAT boilers for the generation of steam might be made of wood is a strange suggestion. That they were at one time so made is illustrated by a model recently prepared for exhibition in the engineering collection of the United States National Museum at Washington. The model depicts a wooden boiler built for the Center Square Pumping Station of the Philadelphia Water Works in 1801. The boiler was essentially an internally fired boiler, the outer skin or shell of which was a rectangular wooden chest enclosing a wrought-iron firebox and flue. The illustrations give a good idea of the external appearance.

The chest was nine feet square inside at the ends and was made of white-pine planks five inches thick, braced upon the top and bottom with oak scantling ten inches square, the whole being securely bolted together by one and one-quarter inch rods passing through the planks. Inside of this chest was an iron firebox twelve feet long, six feet wide and one foot ten inches high, the front of which extended through the front of the boiler with a wide flanged shoulder which was securely bolted to the planks to make a watertight connection. On this flanged part were hung the firedoors. The portion of the firebox back of the doors was the combustion chamber, made slightly higher than the rest, with the top curved slightly upward to form the semblance of a combustion arch. This section was fitted with grates and connected to a vertical ashpit section which extended downward through the bottom of the wooden chest through a watertight fitting.

Back of the combustion chamber the firebox was a wide flat rectangular box, stayed and stiffened by vertical tubular pipes of eight to twelve inches inside diameter which opened through the top and bottom sheets of the firebox. These were in effect water tubes, an example which seems to have been overlooked by the historians of the water-tube boiler. At the back of the firebox, at the top, was connected one end of a flat oval-sectioned flue which extended to the front of the boiler and then back in a large U-bend to the stack at the back of the boiler. In operation, water in the boiler completely surrounded the firebox, ashpit, and flue, and circulated through the pipes that were located in the firebox.



MODEL OF WOODEN STEAM BOILER AT THE NATIONAL MUSEUM WASHINGTON, D. C.

At the time a great gain in economy of operation was supposed to be effected by the nonconducting properties of the wooden shell, and tests did prove that there was a saving. This was found to be only temporary, however, as great difficulty was experienced in keeping the chest water- and steamtight. This boiler, as were all that were tried, was replaced within a few years by a boiler of cast iron. The pressure of the steam that was generated in the boiler was only two and one-half pounds per square inch.

The idea for wooden steam boilers was borrowed by the early engineers directly from the distillers of whiskey. At the time the distillers were having considerable difficulty because of the injurious effect of the mash on the wood, but the steam pioneers considered that it remained to be tried whether "simple steam and water" would have a like effect. After 1801 there was further experimentation with wooden boilers made in conical and other shapes and constructed with hoops and staves as tanks and casks were made. None of these lasted long enough to warrant the continuation of the practice.

STRESSES *in* RUBBER TIRES

By H. HENCKY

LISBON, N. H.

A STUDY of the stresses in automobile tires is of interest because of the size of the tire industry, and the importance in tires of such considerations as riding comfort, length of life, and safety. Such a study depends upon our knowledge of the elastic behavior of rubber.

An attempt will be made to explain the mechanical properties of the reinforcing fabric and the effect of centrifugal stresses and the stresses caused by changes in the speed and direction of the automobile. Although an intensively mathematical treatment of the subject would undoubtedly yield interesting results to the tire designer, this paper will be limited to a statement of the forces involved and the significance, importance, and limitations of the use of these forces in tire design with respect to safety, speed, and wear.

MOST IMPORTANT STRUCTURAL ELEMENT IS OUTER CASING

The principal structural elements of the tire are the inner tube, made of vulcanized rubber, and the outer casing, made of

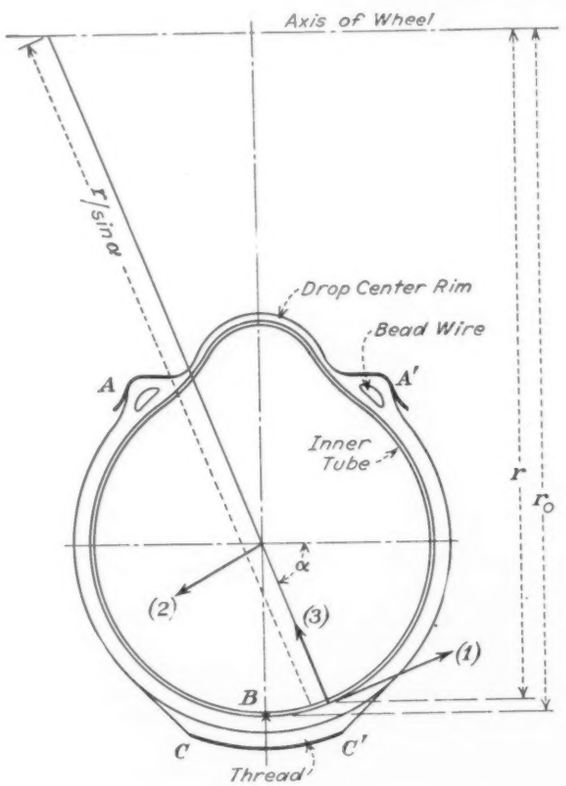


FIG. 1 CROSS-SECTION OF A NORMAL TIRE

especially tough wear-resisting rubber reinforced with cotton cords known as the fabric.

The inner tube is an air-tight bag, pressed against the rim and the outer casing by internal air-pressure, and has no statical function. It is so elastic that the outer casing can be considered, in comparison, inextensible. Naturally, then, the most important structural part of the tire is the outer casing.

The air pressure to which the inner tube is inflated, while formerly as much as 45 to 60 lb per sq in., does not at present exceed 30 to 35 lb. There are now on the market "doughnut" or air-wheel tires with inflation pressures less than 14 lb per sq in. Such tires must be carefully designed with respect to bending action, whereas in the high-pressure tire, with inflation pressures of at least 30 lb, the bending action is of minor importance, the actual stiffness being due to an existing pressure head resulting from the excess of internal over atmospheric pressure.

As shown in Fig. 1, the inflated inner tube presses the bead wires, forming the foundation of the tire, against the rim.

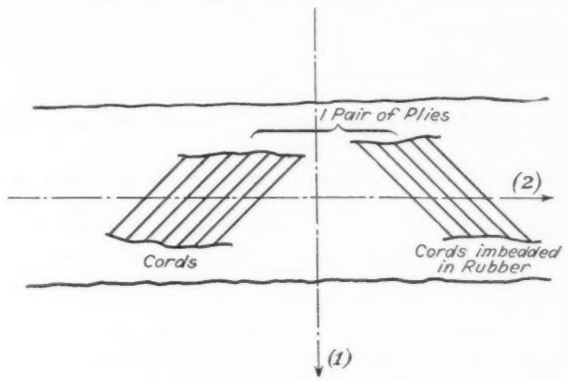


FIG. 2 ARRANGEMENT OF THE PLIES

The three axes of reference used in analyzing stresses and strains, also indicated in Fig. 1, are: (1) tangent to the surface and in the plane of the cross-section, (2) in the direction of the tubular axis and perpendicular to the plane of the cross-section, and (3) perpendicular to the surface and in the plane of the cross-section. These axes are taken with respect to the inside surface of the outer casing.

The manner of reinforcing the outer casing with cotton cords is shown in Fig. 2. These cords are arranged as near the inside surface as possible in layers or plies running at an angle of 45 deg with the tubular axis. Each layer or ply is run at an angle of 90 deg to the ply immediately above or below it so that each pair of plies forms a structural unit equally strong in both directions, 45 deg to the tubular axis. Generally three such units are used, making a six-ply tire.

A square-woven fabric was at one time used where a pair of plies is now employed. Experience showed that this square-woven construction permitted direct contact between the cords, with the result that the friction at these points of contact caused rapid wear and consequent weakening of the stiffening cord structure. The modern ply construction permits each cord to be separated from all other cords which run next to it or across it by a thin protecting and lubricating coating of rubber. This method of construction, by eliminating cord friction, greatly reduces the danger of blow-outs.

THE STRESSES IN THE PLIES

To study the mechanics of a sample reinforced with one pair of plies, a second system of reference axes (1′) and (2′) is intro-

duced as shown in Fig. 3. These new axes coincide with the directions of the cords in the plies and make an angle of 45 deg with the axes (1) and (2) chosen as described in the reference to Fig. 1. Assuming that the total deformation of the elastic surface is small, we have, for the axes (1′) and (2′)

$$S_{1'} = E\epsilon_{1'}; \quad S_{2'} = E\epsilon_{2'}; \quad \text{and } S_{1'2'} = G\gamma$$

where ϵ is the strain, S is the normal stress, $S_{1'2}$ is the shearing stress, E is the modulus of elasticity, G is the modulus of shear,

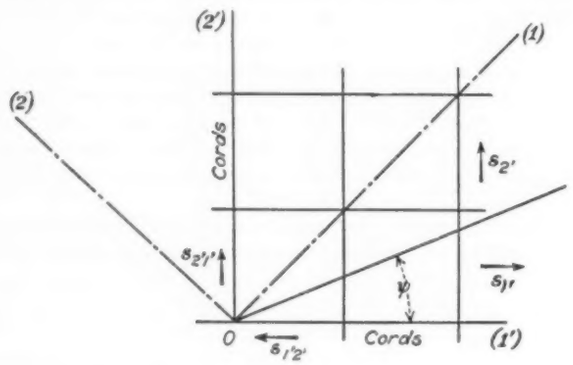


FIG. 3 SYSTEM OF COORDINATES FOR THE STRESSES IN THE TIRE

and γ denotes the change in the angles between the cords in the plies.

It must be remembered that only the total strain of the sample can be considered small. Since the cords do not undergo any noticeable changes, the strain of the separating rubber can be very great.

E is determined by the stiffness of the cords and is more than 100 times the modulus for rubber, while G is only about 10 times the modulus of shear for rubber.

Applying the relations just derived for axes (1′) and (2′) to a new set of axes making an angle ψ with them, and further assuming that $S_{1'2'} = 0$, we have, in the "ψ" direction, for the modulus of elasticity

$$E_\psi = E\cos^2 2\psi + G\sin^2 2\psi \quad \ldots\ldots\ldots\ldots [1]$$

The values of E_ψ for different values of ψ are shown in Fig. 4.

When $\psi = 45$ deg, Equation [1] becomes $E_{45\,\text{deg}} = G$. This means that the ply-reinforced tire has an increase in softness in the directions (1) and (2) which is extremely desirable, since, as we shall see, all of the impact stresses occur in these directions.

The behavior of the tire is elastically quite different for two special cases. If $S_1 = S_2$, the strain, because the plies will not allow any uniform extension in two perpendicular directions, will be much smaller than would be the case if $S_1 = -S_2$. Under this latter condition the plies cannot resist a deformation along the diagonal of the pattern. Consequently, it is necessary to divide and compose the stresses as follows:

$$\left.\begin{aligned} S_1 &= \frac{S_1 + S_2}{2} + \frac{S_1 - S_2}{2} \\ \text{and} \\ S_2 &= \frac{S_1 + S_2}{2} - \frac{S_1 - S_2}{2} \end{aligned}\right\} \quad \ldots\ldots\ldots\ldots [2]$$

One portion of each stress $(S_1 + S_2)/2$ causes no appreciable deformation; the other part $(S_1 - S_2)/2$ does.

Experience has shown tire manufacturers how to combine successfully the cords and vulcanized rubber in the outer casing so as to have all impact forces absorbed in the more elastic parts and allow only the static portions of those stresses to reach the sections of the casing which cannot well deform.

ELASTIC AND INELASTIC BEHAVIOR OF RUBBER

To understand fully the long life of moerdn tires, a deeper study of the elastic and inelastic behavior of rubber is necessary. During the processes of manufacture, of course, the properties of raw rubber are of prime importance. Since the products of manufacture consist of only vulcanized rubber, it is to this kind of rubber that the discussion will be confined. It is quite probable that the molecules of raw rubber do not differ greatly from those of vulcanized rubber.

Researches of chemists indicate that the rubber molecule is in the form of a long chain of atoms coiled up in a manner so irregular that X-ray investigation does not reveal any structure. When stressed, the molecules are stretched and tend to straighten out. The modulus of elasticity, therefore, bears no relation to the forces connecting the atoms. The molecules are held together by secondary attracting forces and by the twisting and entwining resulting from their irregular forms. Such a structure explains two important features possessed by rubber:

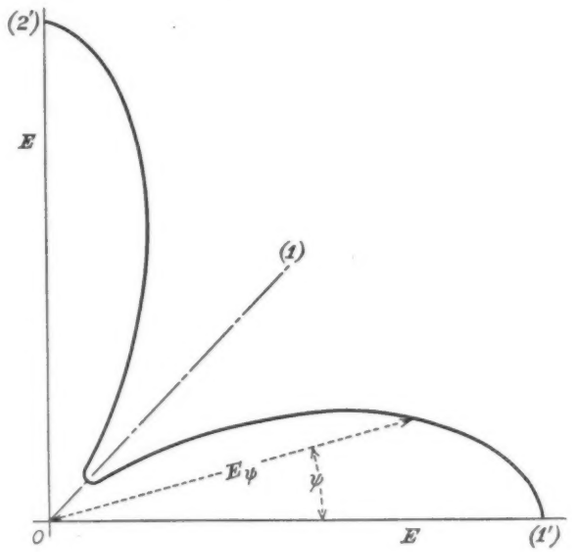


FIG. 4 POLAR DIAGRAM FOR THE MODULUS OF ELASTICITY

First, it has no constant modulus of elasticity; second, there is much internal friction.

Vulcanized rubber has to be considered as a solid. If it is loaded, a condition of static equilibrium will be reached. This fact is emphasized because the solid character of rubber is frequently misunderstood. There is a certain temperature and a certain stress intensity below which vulcanized rubber cannot be forced to permanent creep, in the same way that a crystalline substance has a temperature-creep limit below which it will reach a constant strain under a given load.

The elastic law of rubber has often been the subject of research. It can be represented by a simple formula up to a strain of 100 per cent. Denoting the principal stresses by s_1, s_2, and s_3, the average or hydrostatic portion of the stresses is $s = (s_1 + s_2 + s_3)/3$. Assuming the material to be incompressible, denoting the principal strains by ϕ_1, ϕ_2, and ϕ_3, and noting that, by definition, $\phi_{1,2,3} = \log_e\left(\frac{\text{final length}}{\text{initial length}}\right)$, we have

$$s_{1,2,3} - s = 2G_0\left[\phi_{1,2,3}\, e^{\phi_{1,2,3}} - \frac{1}{3}(\phi_1 e^{\phi_1} + \phi_2 e^{\phi_2} + \phi_3 e^{\phi_3})\right] \quad \ldots\ldots [3]$$

which is an elastic law in agreement with experiment.

Since experiments show that rubber possesses an enormous resistance to changes in volume (the modulus of compressibility being about 400,000 lb per sq in.) we may assume that $\phi_1 + \phi_2 + \phi_3 = 0$ which is the condition of incompressibility.

The modulus of shear G_0 in Equation [3] varies from 50 to 70 lb per sq in. for soft rubber. Naturally, it is possible to manufacture porous rubber with any desired degree of compressibility. The modulus of shear can be greatly changed by mixing other substances with rubber.

In Fig. 5 a mechanical model of the microelements of rubber shows three perpendicular spiral springs enclosed in a casing whose form may be changed but whose contained volume is constant.

Equation [3], in which the function simplest for analytical representation has been chosen, is applicable not only to rubber but, in general, to any elastic colloid under small strains. By "small strains" a condition is indicated wherein none of the absolute values of $\phi_{1,2,3}$ is greater than unity. In technical applications of rubber as an elastic material, a value of ϕ greater than one is never admitted.

Since Poisson's ratio is $1/2$, the modulus of elasticity corresponding to G_0 in Equation [3] is $3\,G_0$. Confusion may arise

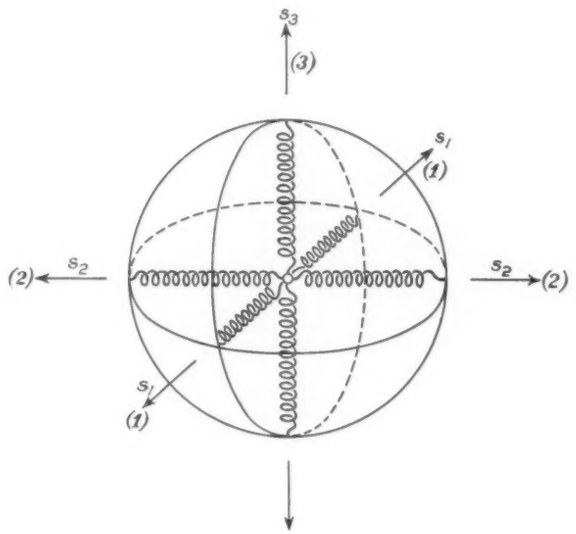


FIG. 5 MECHANICAL MODEL OF THE RUBBER MOLECULE

because the term "modulus of elasticity" has been used in connection with a material that does not follow a linear law of elasticity. This confusion is justified logically because the constant appearing in the law of elasticity does not measure the elasticity of small deformations. For uni-axial stress in the (3) direction, we have

$$s_3 = 2G_0\phi_3\left(e^{\phi_3} + \frac{1}{2}\,e^{\frac{-\phi_3}{2}}\right)$$

The apparent modulus of elasticity for infinitesimal deformations is shown, by differentiating, to be

$$\frac{ds_3}{d\phi_3} = E_0 = 2G_0\left[e^{\phi_3}(\phi_3 + 1) + \frac{1}{2}\,e^{\frac{-\phi_3}{2}}\left(1 - \frac{\phi_3}{2}\right)\right] \ldots\ [4]$$

In Fig. 6 are shown the results of experiments conducted on rubber belts, using varying loads. Knowing the load and the length of the string, and by measuring the time of the free vibration under the load, the modulus E_0 can be calculated. Curves a and a', Fig. 6, give the modulus as calculated from

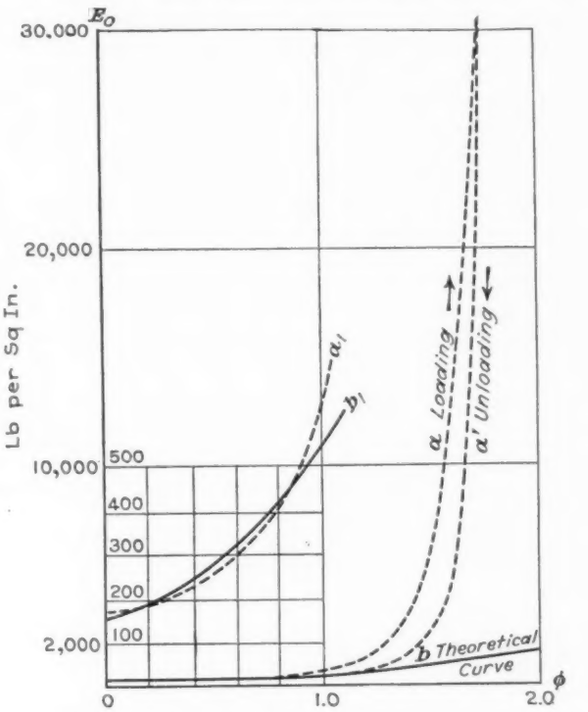


FIG. 6 THE MODULUS OF ELASTICITY DETERMINED BY VIBRATIONS

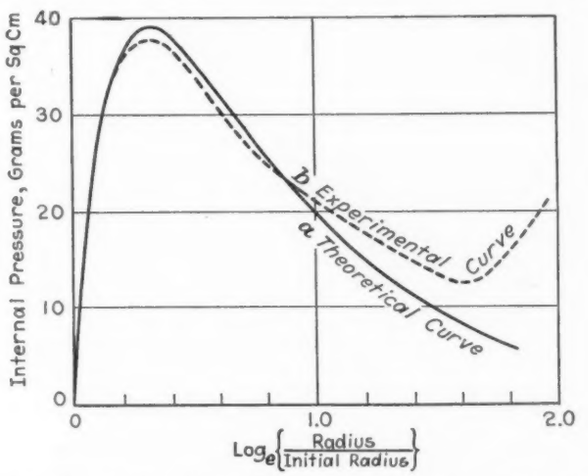


FIG. 7 ELASTICITY AND YIELDING OF THIN RUBBER BALLOONS[1]

loading and unloading conditions, respectively. Curve b is a theoretical curve and corresponds to Equation [4]. Curves a_1 and b_1 are representative of curves a and b plotted to a larger scale.

The gradual stiffening which we notice under increasing load makes rubber the most effective shock absorber.

THE ELASTIC BEHAVIOR OF THE TIRE AS A WHOLE

Although rubber is an excellent shock absorber in itself, it is

[1] The experimental curve is taken from the article of J. R. Sheppard and W. J. Clapson, *Indus. and Eng. Chem.*, vol. 24, pp. 782–790.

not satisfactory in solid form for vehicular tires because under compression the modulus of elasticity is raised as illustrated in Fig. 7, indicating that the shock-absorbing quality of solid tires is exhausted under load. On the other hand, an unreinforced rubber tire filled with air would undergo such enormous deformation that the rim of the wheel would come in contact with the ground, making such a tire equally as unsatisfactory as a solid tire. Between these two impractical extremes we have the high-pressure tire and the low-pressure or air-wheel tire, both utilizing reinforcing cotton cords as described previously.

In order to make a satisfactory analysis of the stresses in tires, it is only necessary to consider the circular form of the cross-section. If a is the radius of the cross-section and r is the radius of the tubular axis, the stresses in the tire under inner air pressure will be about the same as if the tubular axis were straightened out to the length $2\pi r$ with the ends closed. Assuming the thickness of the tire to be uniform, the distribution of stresses resulting from inflation can be expressed as follows:

$$S_r = \frac{a}{h} p \ldots\ldots\ldots\ldots [5a] \qquad S_t = \frac{a}{2h} p \ldots\ldots\ldots\ldots [5b]$$

Where S_r is the stress tangential to the cross-section, S_t is the stress parallel to the tubular axis, h is the thickness of the tire, and p is the internal pressure.

For the case under consideration the combining of Equation [2] with Equations [5a] and [5b] gives the following values for S_r and S_t

$$S_r = \frac{3a}{4h} p + \frac{a}{4h} p \ldots\ldots\ldots [6a] \qquad S_t = \frac{3a}{4h} p - \frac{a}{4h} p \ldots\ldots\ldots [6b]$$

S_r thus ascertained does not change the form of the tire, but S_t shortens the tubular axis of the tire and increases the circumference of the cross-section. Consequently, to obtain a circular cross-section of the inflated tire, the deflated tire must be designed elliptical in shape with the shorter axis parallel with the axis of the wheel.

EFFECT OF CENTRIFUGAL FORCE AND TREAD

The effect that the tread of the tire has on these stresses has been neglected up to this point, which is permissible when making such a study of the stresses. However, if the centrifugal force resulting from the angular velocity of the wheel is to be considered, the effect that the tread has upon these stresses must be known. The determination of the S_r and S_t components of the centrifugal stresses is an involved calculation which becomes quite elementary when the S_r component is neglected.

The centrifugal force due to the angular velocity of the wheel can be expressed as $\frac{\gamma}{g} \omega^2 (r + a)$, and S_t, the stress parallel with the tubular axis resulting therefrom, is given by the equation

$$S_t = \frac{\gamma}{g} \omega^2 (r + a) \frac{(r + a)}{h} \ldots\ldots\ldots\ldots [7]$$

where γ is the weight of the tread per unit area of tire surface, ω is the angular velocity of the wheel, g is the acceleration due to gravity, and $(r + a)$ is the distance of the tread from the center of the wheel.

Introducing v, the speed of the car, the angular velocity of the wheel $\omega = v/2(r + a)\pi$. Substituting this expression of ω in Equation [7] and reducing

$$S_t = \frac{\gamma}{g} \frac{v^2}{4\pi^2 h}$$

Applying this expression in Equation [2]

$$S_r = \frac{S_t}{2} - \frac{S_t}{2} \ldots\ldots [8a] \qquad S_t = \frac{S_t}{2} + \frac{S_t}{2} \ldots\ldots [8b]$$

From these latter equations it is seen that S_r, the centrifugal-stress component tangential to the cross-section, becomes zero, and that S_t is the only component of the centrifugal stress which affects the tire, which affect will tend to increase the length of the tread and tubular axis.

A comparison of stresses set up in the tires of a light sedan by inflation and by centrifugal force, as determined from Equations [6a] and [6b] and Equations [8a] and [8b], respectively, can now be made. For the purpose of such a comparison, $(r + a)$ is given as 40 cm; γ as 2×10^{-3} kg per sq cm; p as 1.5 kg per sq cm; h as 0.5 cm; a as 5 cm; and g as 981 cm per sec per sec. For a given speed of 20 mph, v becomes 9 meters per sec.

Substituting these values in Equations [6a] and [6b], the stresses due to inflation are

$$S_r = 11.2 + 3.7 \text{ kg per sq cm} = 160 + 52 \text{ lb per sq in.}$$
$$S_t = 11.2 - 3.7 \text{ kg per sq cm} = 160 - 52 \text{ lb per sq in.}$$

Although these stresses are approximately the same as the modulus of elasticity of pure rubber, they result in but a slight deformation of the tire because the stresses mainly responsible for whatever deformation exists are much smaller than the modulus E as determined from Equation [2], which is the modulus of the reinforced rubber in the tire.

Substituting the given data in Equation [8b] and solving for the stress parallel with the tubular axis that is set up by the centrifugal force

$$S_t = 0.08 \text{ kg per sq cm} = 1.2 \text{ lb per sq in.}$$

This stress is so small that it need not be taken into consideration. However, this stress becomes a factor when analyzing the stress distribution in racing-car tires and special heavy tires and a correction must be made for it when designing such tires in order to minimize the deformation due therefrom.

THE INFLUENCE OF LOCAL LOADS

All the stresses heretofore considered are caused by inflation and centrifugal forces and are evenly distributed over the whole tire. There are, however, in addition to these stresses, the stresses resulting from suddenly applied, local loads.

Considering the balloon or low-pressure tire, it is obvious that inner air pressure causes little or no stress in the casing. However, when loaded by the weight of the car, it will flatten out at the point of contact until the area of the surface of contact multiplied by the total inner pressure equals the load on the wheel. With reference to Fig. 1, the wheel load effects an increase in the curvature of AC and $A'C'$, and a flattening of the section CC'. Inasmuch as the stress is proportional to the radius of curvature multiplied by the inner air pressure, the stress in sections AC and $A'C'$ will be smaller than in the section CC'. Although such a deformation of the tire will compress the volume of air in the inner tube and increase the inner pressure accordingly, the inflation stresses resulting therefrom can be neglected because the increase in pressure amounts to but one half of one per cent of the initial pressure. Also, since S_t is a tensional stress parallel to the tubular axis caused by inflation or by a combination of inflational and centrifugal forces, the load on the wheel will result in a decrease in S_t, because such a load compresses the tread of the tire parallel with the tubular axis by bringing the various points of the tire nearer to the axis of the wheel, thus decreasing the circumference of the tread.

We have, therefore, the somewhat paradoxical result that wheel loading effects a decrease in tire stresses. This, however, is untrue, because there are bending stresses set up by changes of curvature of the casing.

EFFECT OF FRICTION IN THE TIRE CASING

If we consider the car in motion, the rapid loading and unloading of the tire shifts the strain to and from the points of contact around the circumference and develops considerable internal friction within the casing with a consequent rise in temperature. This temperature rise is greatly augmented by the external friction of the tread on the road. Of these two types of friction, the latter causes the greatest rise in temperature and is the most important factor to be considered when designing a high-speed tire, inasmuch as the danger in high-speed driving arises from the impossibility of the material to dissipate the heat or energy concentration from the places where it is generated.

The external friction of rubber is a most embarrassing factor and often deceives the investigator. In Fig. 8 is shown a rubber cylinder AA_1CC_1 which is unable to deform along the line AA_1 but able to slide along the line CC_1 although hindered somewhat by friction. In the tire, the line AA_1 can be identified with the surface of the tire adjacent to the rim while the line CC_1 corresponds to the tread. If the line AA_1 is moved downward by some external pressure, the points C and C_1 will remain under the influence of friction. Under this external load, the cylinder will first assume the form $A'B'C$ and $A_1'B_1'C_1$.

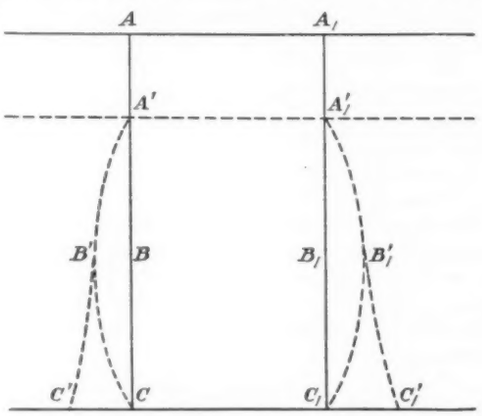


FIG. 8 RELAXATION OF BOUNDARY STRESSES

With increasing pressure, however, a certain relaxation of the frictional resistance sets in and the point C and C_1 will move to C' and C_1'. The elastic energy accumulated in the position $A'B'C$ and $A_1'B_1'C_1$ is greater than the elastic energy accumulated in the position $A'B'C'$ and $A_1'B_1'C_1'$ and the tendency to relax is exactly proportional to the difference between these amounts of energy. That means that an infinite time is needed for complete relaxation. Many investigators have already come to the erroneous conclusion that the relaxation takes place inside the specimen. Such an error of judgment can be corrected by compressing the specimen in a testing machine and measuring both the strain in the rubber and the change in distance between the moving head and the platen.

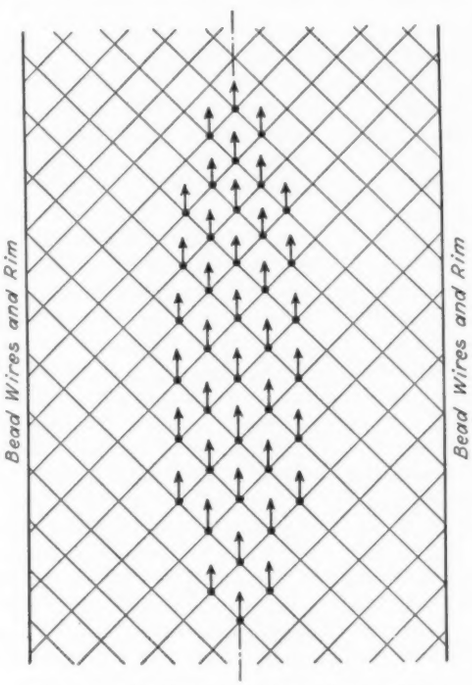


FIG. 9 IMPACT IN THE DIRECTION OF THE TUBULAR AXIS

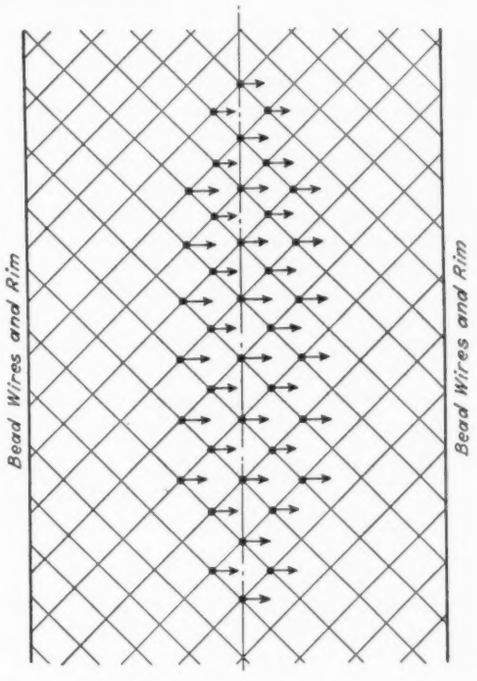


FIG. 10 IMPACT THROUGH DIRECTIONAL CHANGES IN THE MOMENTUM

Although external friction increases the temperature of the casing, the tire designer cannot attempt to limit this temperature rise to a minimum by developing a vulcanized-rubber product for the tire casing which will have a small coefficient of friction. If he does this, he will produce a hard tire which will have little external friction and therefore a tire that will have long life but also one that will favor skidding. Consequently, a product must be developed that will have a coefficient of external friction sufficiently large to prevent the tire from skidding and yet must be sufficiently small to minimize tread wear and give maximum mileage. The balloon tire is a step forward in this direction and will probably diminish accidents due to skidding, because, being soft, it has a larger contact surface with the road and, therefore, resists changes in the direction of car momentum.

When skidding does occur as a result of sudden changes in either the magnitude of the momentum or the direction of momentum of the car, the impulse is transmitted at 45 deg to the tire cords, as illustrated in Figs. 9 and 10, and causes a comparatively large strain which breaks the impact.

Braking and starting also cause high stresses to be set up in the tire, but when the forces are transmitted to the rim of the wheel they can be considered as statical loads, since the kinetic energy developed in the tire has been dissipated as internal friction and elastic deformation. A study of the distribution of these stresses is, however, quite complicated, and it is doubtful if the tire designer would be interested in the calculations.

DUST CONTROL

Present and Future Design Considerations

By THEODORE HATCH

HARVARD SCHOOL OF PUBLIC HEALTH

FOR many years there has been a vague understanding of the relation between industrial dust and disease. Thus we find such names as "potter's rot" and "miner's consumption" antedating the relatively modern word "silicosis." In a few instances, notably in the South African gold mines, silicosis has been known for some time and has been accepted as a definite liability of the industry. In the United States also, certain sections of the mining industry were made aware of the dust hazard at an early date and a few sporadic studies were made in other industries, but with these exceptions workmen and employers alike were not generally cognizant of the danger of dust. This is especially true of the "new" industries in which the disease has not had time to establish itself as a tradition.

Although scientific methods for the detection of silicosis and requirements for its control have been developed, there has been no comparable progress toward its elimination. A review of state regulations of the dusty trades shows that they do not meet the present requirements of the problem and that satisfactory results cannot be expected with the methods of inspection and evaluation of control equipment now generally employed. Workmen's compensation acts did not originally provide for payment for incapacity resulting from occupational dust diseases, and at the present time only five states allow compensation for silicosis. Even in these one may say that it secured its place by default, for in no case is the disease specifically mentioned.

In the face of this unsatisfactory situation there has been a tremendous increase in the number of claims during the past few years. Most of these have been presented for settlement under the common law and thus the complicated and highly technical details of the problem have come before lay juries for consideration and judgment. Conflicting testimony has been given by medical and technical witnesses and the whole situation has become more confused as a result. It is evident that the *legal* aspects of the dust problem need revision and clarification, but regardless of the merits of settlement under common law compared with operation under a compensation act, the fact is that the *hygienic* and *economic* aspects of the problem can be settled only through permanent elimination of dust from industry. It is desirable, therefore, to inquire into the present status of engineering design of dust-control equipment.

PRESENT STATUS OF ENGINEERING DESIGN OF DUST-CONTROL EQUIPMENT

Textbooks on ventilation and engineering handbooks devote little or no space to methods of control of industrial dust, and in the technical journals, papers on fundamental engineering design of equipment are conspicuous by their absence. In a recent bibliography of the literature on pneumoconiosis, less than one per cent of the articles dealt with the engineering control of the disease. The *science* of dust control has not developed beyond the stage of trial and error, and the design of structures for the suppression of dust is based almost entirely upon empirical data together with one or two elementary formulas. The latter were derived from the generalized experience in a limited number of industries, such as woodworking, where conditions and requirements are not at all like those, for example, in a sand-pulverizing plant. Wide experience and good judgment are essential to the proper use of the scanty information that has been collected and systematized. Without attempting to minimize the importance of experience in engineering design, it is necessary to point out that most of the past experience obtained in the empirical design of dust-control equipment was not evaluated by means of quantitative studies of the actual reduction in dust. Hence, past experience does not necessarily furnish the proper guide for future design. In fact, recent surveys in certain industries, employing modern methods of investigation, have shown that existing equipment is in many cases inadequate.

Dust *control*, as practiced today, is to some extent the offspring of dust *collection*, but since they are opposite in purpose, the requirements of one are not necessarily like those of the other. Thus, manufacturers of dust collectors may guarantee collection of $99^1/_2$ per cent and in the production of a commercial powder this is entirely satisfactory, but it has no meaning in the performance of dust-control equipment. It is the escaping dust, not that collected, which is important, and guarantees of performance must be based upon permissible amounts of dust at the breathing zone of the workmen and in the "clean" air discharged from the equipment. For example, assume a safe limit of dustiness in the air discharged from a certain plant to be 1 mg per cu m or 0.000044 grain per cu ft and assume also a dust loading of 30 grains per cu ft. Under these conditions, which are not abnormal, the efficiency of dust "collection" must be 99.9985 per cent!

PRESENT STATE CODES INADEQUATE

Specifications in state codes for the design of exhaust hoods are commonly written in terms of the "static suction" to be maintained at the throat of the hood. Contrary to a widespread idea, suction per se has no effect in the capture of dust. The use of this index arises from the fact that it constitutes an approximate measure of the rate of airflow into a suction hood. This is true, however, only when the area of the throat and the size and shape of the hood are also given. In fact, as the following equation shows, these two factors are more important than the static suction, since the latter operates only at the one-half power

$$Q = 4000Af\sqrt{h}$$

where Q = rate of airflow at 65 F, cfm; A = area of throat, sq ft; h = static suction at throat, inches of water; and f = coefficient of restriction, which varies considerably with hood design.

Increasing mortality rates among workmen exposed to harmful dusts demonstrate the need for changing the regulations.

Contributed by the A.S.M.E. Safety Committee and presented at the Annual Meeting, New York, N. Y., December 3 to 7, 1934, of The American Society of Mechanical Engineers.

In Wisconsin the new general orders issued by the Industrial Commission require hazardous plants to maintain atmospheric conditions below certain permissible standards established by recognized authorities. Thus structural details of control equipment are made secondary to results. Similar requirements have been incorporated in the proposed codes for other states. But with their adoption, it must be made clear that permissible values of dustiness are not absolute and may change as our knowledge increases. State requirements must therefore be kept flexible to allow for revisions dictated by new evidence and changes in "good practice." In order to facilitate this work and secure uniform requirements throughout the country, a national board is proposed whose purpose would be to review evidence and methods and prepare at stated intervals, for the assistance of state officials, standards of good practice for various dusty processes and industries.

The systematic correlation of actual results with the details of design, coupled with an understanding of the physical properties of dust and the laws governing its dispersion and behavior in the air, will provide a body of facts upon which to base the engineering design of equipment. Some of the fundamental factors are considered in the present paper.

PHYSICAL PROPERTIES OF DUSTS

Suspensions of dusts and fumes in the atmosphere, although possessing greater particle size, may be compared to a certain extent with colloidal systems. Gibbs has given the name "aerosol" to the dispersed system in which solid or liquid particles are dispersed in a gas. Aerosols differ, however, in their physical properties from hydrosols (dispersing medium a liquid). First, the settling rate of the dispersed material is very much higher, and second, molecular activity and therefore Brownian motion is greater. Consequently, the particles collide more frequently and the tendency toward flocculation is increased. Finally, aerosols differ in their electrical properties. Some particles carry positive charges, some negative, and some may be neutral; in a liquid medium, on the other hand, all particles generally have the same charge.

The formation of aerosols results from processes of dispersion including mechanical grinding, crushing and shattering, explosions, etc. Energy must be introduced to overcome the force of cohesion of the original material and the amount of energy required is roughly proportional to the area of new surface formed. The size of the particles produced depends upon the manner in which the shattering force is applied and also upon the geological structure of the material being crushed. Thus Jones[1] (1) has pointed out that in the South African "banket," the fibrous sericite, which occurs as a cementing material between the particles of quartz, is more easily broken down during drilling and blasting than the solid grains of silica and appears in the dust, therefore, in smaller sizes.

The physical properties of a material may be greatly altered from the original when it is finely ground and dispersed. The surface area and specific surface are enlarged many times and the rate of evaporation and solution as well as the adsorptive capacity are thereby greatly increased. Chemical activity also increases, since there is a larger proportion of unbalanced molecules lying at the surface. Aerosols differ also from one another in their physical properties, depending upon the degree of dispersion. It is convenient, therefore, to distinguish between different classes of aerosols. Gibbs's classification (2) is based upon the settling rate of particles in air:

(1) Dusts: Particles greater than 10 microns, settle with increasing velocity.

(2) Clouds: Particles 0.1 to 1.0 micron, settle with uniform velocity, according to Stokes's Law.

(3) Smokes: Particles 0.001 to 0.1 micron, do not settle in air.

Drinker (3) has modified Gibbs's classification and combined the idea of source of material with the degree of dispersion. It is more descriptive and conveys more meaning although it is physically less exact than Gibbs's grouping.

(1) Dusts: Particles 1 to 150 microns, generated by mechanical agencies such as crushing, grinding, drilling.

(2) Fumes: Particles 0.2 to 1.0 micron, resulting from chemical reactions such as distillation, complete and incomplete oxidation of metals.

(3) Smokes: Particles less than 0.3 micron, usually resulting from incomplete combustion of carbonaceous matter.

These classifications are valuable when considering methods of air cleaning and other problems related to dust control, since the method of treatment suitable to one class of suspension may be of no value in the case of another. Cyclones, for example, are valuable for the capture of coarse dusts, but despite the claims sometimes made for them, they cannot be depended upon to remove the fine material of hygienic importance.

MOTION OF PARTICLES IN AIR

Particles suspended in a gas are subject to two forces—external and internal. The former includes gravitation, centrifugal force, and electrical attraction. Internal forces result from molecular activity of the gas and from electrostatic charges carried by the particles.

External forces acting upon particles suspended in air cause them to move through the air with velocities that vary with the size, shape, and density of the particles, and with the density and viscosity of the air as well as with the strength of the external force.

The resistance to travel of spheres through a motionless gas may be written (4) $R = ka^n\rho\gamma^{(2-n)}V^n$, where a = radius of the particle; ρ = density of gas; γ = kinematic viscosity of gas; V = velocity of travel of particle; k = constant. In the region of streamline motion $n = 1.0$ and hence $R = ka\rho\gamma V$. This is the equation developed by Stokes for the resistance of small particles moving at low velocities. The resistance varies directly with particle radius and velocity. Large particles traveling at high velocities, on the other hand, set up turbulent motion. In this region $n = 2.0$; the resistance to motion becomes a function of the squares of velocity and particle diameter, and the viscosity effect is eliminated, thus $R = ka^2\rho V^2\gamma^0$.

Under the attraction of gravity, suspended particles fall with increasing velocity until the gravitational force $F = 4/3\pi a^3(\sigma - \rho)g$ is just balanced by the resistance R. At this point acceleration becomes zero and the settling velocity reaches a constant value which may be determined for the two forms of motion by the following equations

$$V = \frac{2}{9}\left(\frac{\sigma-\rho}{\rho}\right)\frac{g}{\gamma}a^2 \text{ (streamline)} \quad [1]$$

$$V = \left[\left(\frac{4\pi g}{3k}\right)\left(\frac{\sigma-\rho}{\rho}\right)a\right]^{\frac{1}{2}} \text{ (turbulent)} \quad [2]$$

Theoretically and experimentally, it has been shown that particles of quartz under approximately 75 microns in diameter settle according to the first equation, and that the particles must be greater than 2 mm in diameter to obey the equation of turbulent motion. Between these two limits is the region in which, according to Allen (loc. cit.), the resistance varies with velocity and particle diameter to the 3/2 power.

[1] Numbers in parentheses refer to bibliography at end of paper.

DISPERSION OF DUST INTO THE ATMOSPHERE

Dust particles, generated by whatever means, require energy for their dispersion from the point of origin into the surrounding atmosphere. Physically, this is provided in only two ways:

(1) Dynamic projection due to the kinetic energy of the particles themselves, imparted to them during their formation.

(2) Dispersion by means of air currents created by the operation of the dusty process.

The counter forces set up by the exhaust hood or other control device for the purpose of preventing the dispersion of dust must therefore be directed, in the first case, against the energy of the dust particles, and, in the second, against that energy which produces air currents around the machine. Since these forces of dispersion are quite different in form, it is clear that proper design of equipment depends upon an understanding of their relative magnitude and the manner in which they act. The first lends itself to approximate mathematical analysis which follows; the second depends upon the action of the dust-producing machine, and its evaluation requires careful analysis of the details of operation of the process.

DYNAMIC DISPERSION

A particle with mass m thrown off with an initial velocity V_0 possesses the kinetic energy

$$\text{K.E.} = \tfrac{1}{2}\, mV_0^2$$

and is resisted, as it travels through still air, by a force which varies with the type of motion and is determined by the equation

$$R = ka^n\rho\gamma^{(2-n)}V^n$$

Neglecting the force of gravity, the particle will travel along its path with a decreasing velocity until at a certain distance S the kinetic energy will be destroyed, i.e., its velocity will be zero. Thus

$$\int_{V_0}^{0} R\,dS = \tfrac{1}{2}\, mV_0^2 = \int_{V_0}^{0} -mV\,dV$$

Within the region of Stokes's law, $R = kV$, and therefore

$$\int_{V_0}^{V} dV = \int_{0}^{S} -k'\,dS$$

which, after integration, becomes $V = V_0 - k'S$. The value of k' ($k' = 3 \times 10^{-4}/a^2$ for spheres) varies inversely with the square of the particle diameter; doubling the size increases the length of travel four times for the same final velocity. For a 10-micron particle having an initial velocity of 5×10^3 cm per sec (10,000 fpm), $S = 4$ cm when $V = 0$.

If the particle travels with turbulent motion, however, the resistance varies with V^2 and we may write

$$\int_{V_0}^{V} \frac{dV}{V} = \int_{0}^{S} -k'\,dS$$

and from this

$$V = V_0 e^{-k'S}$$

Here $k' = 3 \times 10^{-4}/a$ for rounded bodies. The particle must travel an infinite distance to reach zero velocity but will, on the other hand, attain a low finite value of V in a finite distance. A particle with a diameter of 2 mm, for example, projected with the same initial velocity as in the previous example (10,000 fpm), will have a velocity of only 10 cm per sec (20 fpm) after traveling approximately 2000 cm or 67 ft.

These equations are not absolutely correct nor do they hold over the entire range indicated. The calculated values of S are therefore not exact. Nevertheless, they are correct in their relative orders of magnitude and to this extent they demonstrate an important principle, namely, that whereas large particles may be dispersed by dynamic projection through still air, microscopic particles, because of their relatively enormous surface area per unit volume, do not travel any appreciable distance by virtue of their own kinetic energy.

This principle is well illustrated by the action of a grinding wheel. Large particles are thrown off by centrifugal force and may be projected a considerable distance through still air, as the path of incandescent particles so clearly indicates. This force is not great enough, however, to disperse the fine particles. Some may be carried in the air stream created by the "drag" of the large particles and thus escape with them. To a greater extent, however, their dispersion is caused by air currents set up by the fan action of the rotating wheel. It follows, therefore, that an exhaust hood placed in the path of the incandescent large particles may not be sufficient, for this neglects the fine (and non-luminous) dust that is dispersed with escaping air currents around the periphery of the wheel.

The concept of the dual function of an exhaust hood, which arises out of the foregoing analysis, suggests that for successful dust control, three things must be done:

(1) The kinetic energy of the large particles must be destroyed. These particles are not important hygienically but they must be captured in order to prevent the escape of fine particles in the air stream created by their "drag." Their energy can be destroyed by means of barriers against which the particles impinge and lose their velocity, and the air currents induced by their motion can be dissipated by setting up counter currents in the zone of dust generation by means of air flow into the exhaust hood.

(2) Air currents created by virtue of the operation of the dusty processes must be eliminated through changes in the machine, or more generally by the application of suitable baffles and housing to prevent their formation.

(3) Air currents around the machine that cannot be eliminated must be changed in direction and made to flow into the exhaust system. This is accomplished by means of the potential gradient established between the suction opening and the surrounding air. Through hood design, the gradient must be maintained at the proper slope from the area of dust-production and at a minimum slope from the so-called ineffective areas in which no dust is produced. A knowledge of the aerodynamic characteristics of suction openings (5) is therefore essential to proper design.

Fundamental specifications for exhaust hoods cannot be established simply from a consideration of these factors. Experimental investigation must remain the most valuable aid to design. Nevertheless, the creation of a real science of dust control, which has been made necessary by the widespread industrial dust hazard, must be based upon physical laws. Empirical methods cannot be depended upon to relieve the heavy financial load that the dust hazard has placed upon industry.

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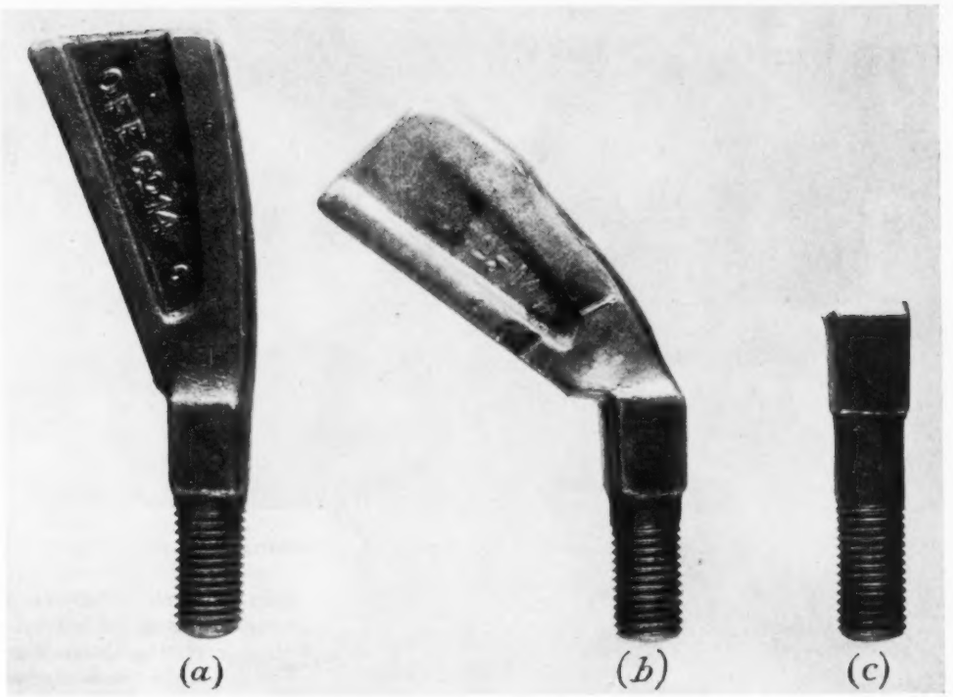

FIG. 1 SEPARATOR TEETH SHOWING FATIGUE CRACKS

Stress Analysis of FAILURES *in* MACHINE PARTS

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UNIVERSITY OF MICHIGAN

A MACHINE part which has failed in service may be a potential gold mine and should be relegated to the junk pile only after all possible information with respect to the reason for the failure has been extracted. The machine designer must receive the benefit of results of investigations of improper practices whether of the nature of metallurgy, fabrication, design, or maintenance.

Failures occur in practice even after the exercise of apparently precautionary measures. Industrial inspection services demand substantial appropriations and still business suffers vast annual expenditures as a result of failures. A weak link in the present system is a disregard for a proper study of parts which are fractured in service. A searching study of the causes of failure should consider the type of loading and the distribution of stresses during the life of the structure. Fatigue resulting from insufficiently large fillets, keyways, shrink-fits, and non-homogeneities in the metal is responsible for numerous important failures in parts subjected to variable stresses. Machine failures which should be carefully analyzed on the basis of stresses are frequently encountered in axles, crankshafts and connecting rods, bolts, boiler heads, and springs.

The metallurgist, in whose hands too often rests the sole responsibility for investigating the broken parts and prescribing a remedy, is usually untutored in stress analysis either as a theorist or experimentalist. Engineering colleges at the present time do not equip men for problems of stress analysis of failures in machine parts. Problems of this nature which arise in industry will find a more ready solution when engineering colleges develop experts who will be able to give scientific analyses of failures which occur in practice. Test cases of actual breakages may be built up in a manner similar to that employed in the law. Industries will furnish the feeding ground and receive immediate benefit from reports. A qualitative analysis is often sufficient and only the more complicated problems require an exact quantitative investigation.

The need for a systematic study of failed machine parts has prompted the establishment of a group of test cases, some of which are reported in this paper. An analysis of the failures and recommendations for proper design are made on the basis of considering the type of stress condition and the form of the structure.

FATIGUE FAILURES

FILLETS INSUFFICIENT

Separator Teeth. The grain in the threshing process passes by numerous teeth, some of which are set in a rapidly rotating cylinder while the others are stationary (Fig. 1). These

Contributed by the Applied Mechanics Division and presented at the Annual Meeting, December 4 to 7, 1934, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

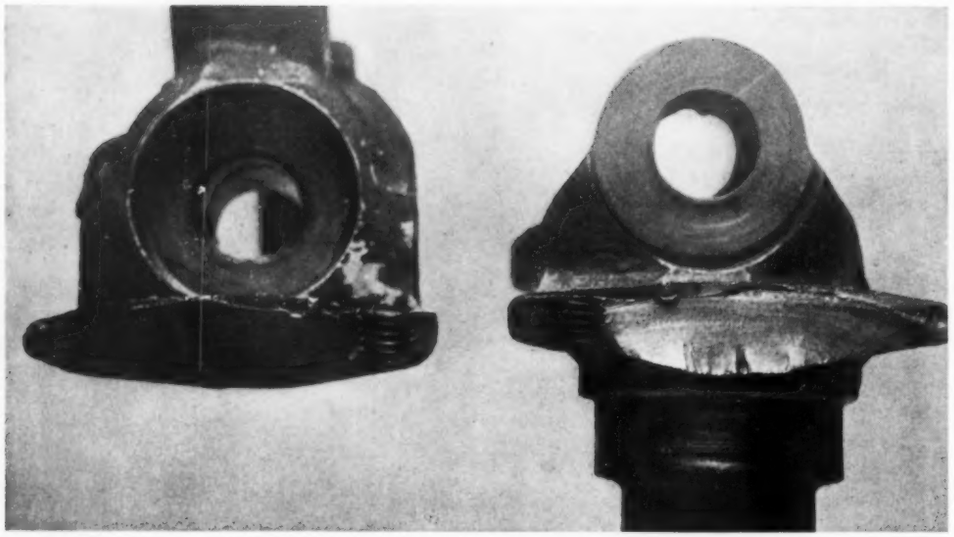

FIG. 2 BROKEN FRONT AXLE OF AUTOMOBILE

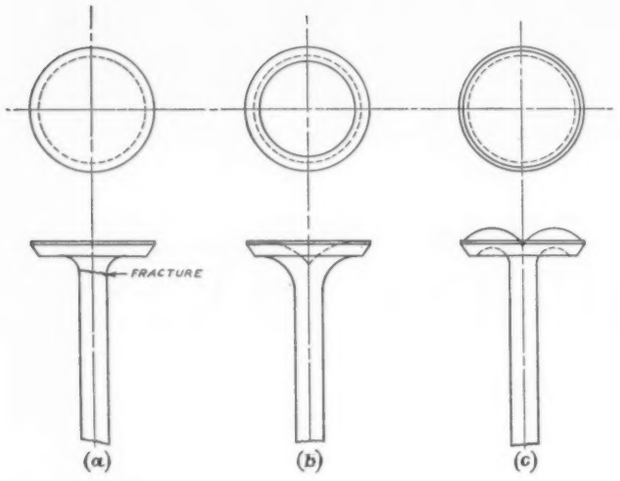

FIG. 3 INTERNAL-COMBUSTION-ENGINE VALVE
(*a*, Conventional design of internal-combustion-engine valve; *b* and *c*, methods of improving design.)

teeth are subjected to periodic forces in the direction of travel of the grain, and, because of the stagger construction, the teeth are also bent first to one side and then the other. Frequent failures occur at the junction of the tooth and the bar to which it is attached. The fractured surfaces indicate definitely the presence of fatigue cracks emanating from the front or tension part and from both sides.

The teeth serve as cantilever beams in fatigue with not only a very small cross-section at the point of maximum bending moment but with a condition of severe stress concentration. The sharp change of section between the base of the tooth and the bar into which the tooth is bolted provides favorable conditions for the beginning of fatigue cracks.

The design can be vastly improved by increasing the section at the base of the tooth in such a way as to provide a flange to discourage such great flexure at the point where the tooth enters the bar.

A secondary type of failure which has been observed consists of backward bending of the tooth, as in Fig. 1*b*. The presence of a flange to correct the more frequent trouble will assist in maintaining the tooth in its original position.

Automobile Front Axle. The front axle of an automobile is a practical illustration of a fatigue test of a cantilever beam. Where the bending moment is greatest, at the attachment to the part of the casting connecting the frame, too small fillets may easily cause stress concentration with resulting fatigue failure. The static weight of the car imposes a steady tensile stress at the fillet at the lower side of the axle and a variable stress is superimpressed whenever the car is in motion. The higher the steady stresses, the lower the variable stresses must be for safe design. A broken front axle of a car is shown in Fig. 2.

When it is impractical to make larger fillets tangent to the two parts of the casting it joins, undercutting may prove decidedly advantageous.

Valves. Fractures of valves in automobile and airplane engines which occur during operation often lead to inconvenience and serious trouble. The break usually takes place in the stem or near the base of the fillet joining the valve. According to T. T. Neill,[1] a particularly large number of failures of parts in airplane motors are valve breakages, most of which result from faulty design rather than faulty material.

[1] "Failures of Aircraft Engine Parts and Causes Thereof," T. T. Neill, Symposium on Aircraft Materials, A.S.T.M., 1930, pp. 78–87.

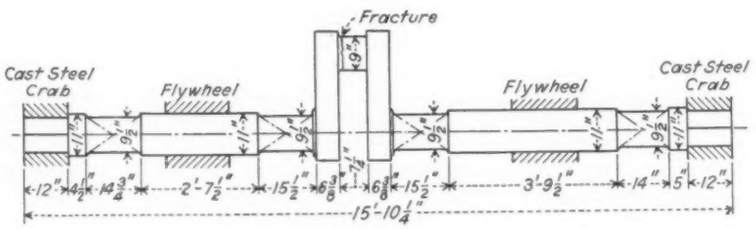

FIG. 4 CRANKSHAFT OF ROLLING-MILL ENGINE

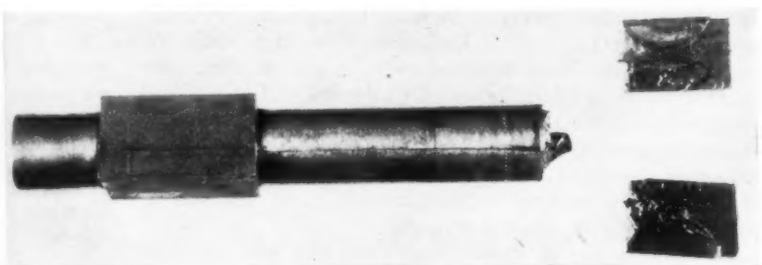

FIG. 5 SHAFT WITH WOODRUFF KEYWAY

The part of the stem at the small end of the fillet, as shown in Fig. 3*a*, is subjected to periodic tension stresses by both direct and bending action. An increase in the radii by the construction as shown in Fig. 3*b* and *c* will tend to reduce the number of failures of this kind.

Crankshaft. A fracture of frequent occurrence is that of the crankpin of a crankshaft. Fig. 4, a drawing of a crankshaft of a rolling-mill engine, serves admirably as an example. The mill jammed frequently, which increased the effect of the reciprocating force applied by the connecting rod on the crankpin. The fracture at the base of the small fillet of the crankpin resulted, finally, after four years of service from stress concentration and the variable stress.

The remedy prescribed consisted of increasing the diameter of the crankpin on the new crankshaft from 9 to 10 inches. The beneficial effect accomplished by such a revision in design is slight compared with the improvement which might have been made by increasing the fillet radius. Sometimes undercutting the crank arms will permit a larger fillet.

Shaft With Woodruff Keyway. The shaft is typical of a large number of torsion-fatigue failures resulting from high stress concentration originating at the sharp reentrant corner of the keyway. Fig. 5 shows the main spindle which supported the drum of a washing machine. The load on the shaft pulsated, and the mechanism caused the drum to revolve first in one direction and later in the opposite direction. Such a stress condition may result in a fatigue failure, particularly when prompted by the presence of a sharp-cornered keyway.

As in this instance, fatigue cracks developed gradually from the sharp reentrant corners of the keyway and spread until the remaining material of the spindle was insufficient to sustain the required load. Final fracture occurred abruptly.

It is interesting to note that shear cracks are evident in both the axial and circumferential directions corresponding with the directions of the maximum shearing stresses.

One would be led to recommend the use of a milling cutter with the corners slightly rounded and a key to fit.

ABRUPT CHANGE OF CROSS-SECTION WHERE FILLETS CANNOT BE USED

Shrink-Fit Collar. The broken locomotive-truck axle described here was originally investigated in the usual manner by metallurgists. Later it was found necessary, in order to correct the trouble, to alter the design features. The bending moment in the vicinity of the collars, Fig. 6, which were shrunk on to the axles and supported the load, was a maximum. The sharp change in cross-section at each side of the collar aggravated the already high stresses so that fatigue cracks ultimately produced fractures at these two sections. The completed fracture is shown in Fig. 7, and the incipient break can also be observed nearer the flange.

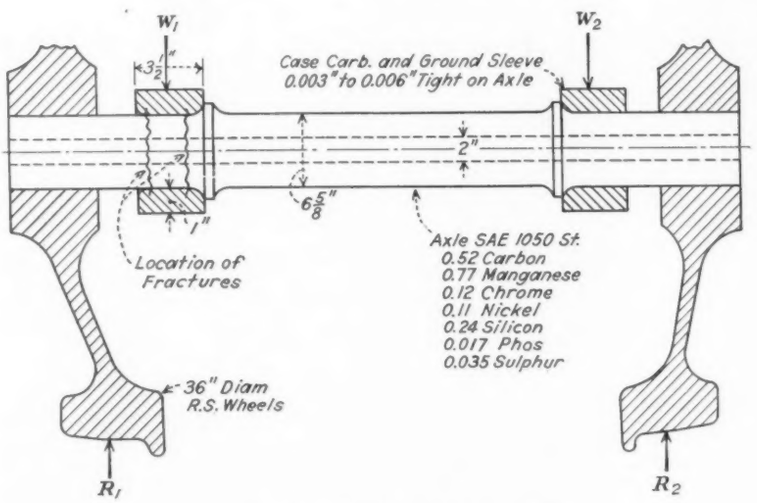

FIG. 6 LOCOMOTIVE-TRUCK AXLE

FIG. 7 LOCOMOTIVE-TRUCK AXLE SHOWING COMPLETE AND INCIPIENT FRACTURES

Correction of this difficulty might involve a series of experiments, but it would be reasonable to begin a study to improve this condition by tapering the collars down gradually at each side in a manner similar to that which would be provided by large fillets, i.e., provide flexible ends on the collars.

Bolts and Nuts. A tendency for bolts to break in situations which promote fatigue action has demanded study. In instances of fatigue which require special design of bolts, designs as shown in Fig. 8*c* and *d* [2] have been advocated. The tendency for the ordinary type of bolt to fracture at the section near the under side of the nut has prompted the new design of a nut which makes the lower part of the nut more flexible. This allows the stress to be redistributed more evenly along the height of the nut.

SECTION UNDERSIZE

Torsion Spring. A source of great inconve-

[2] "Die Dauerhaltbarkeit von schraubenverbindungen und Mittel zu ihrer Steigerung," by A. Thum and H. Weigand, *Zeit. V.D.I.*, vol. 77, no. 39, Sept. 30, 1933, p. 1061.

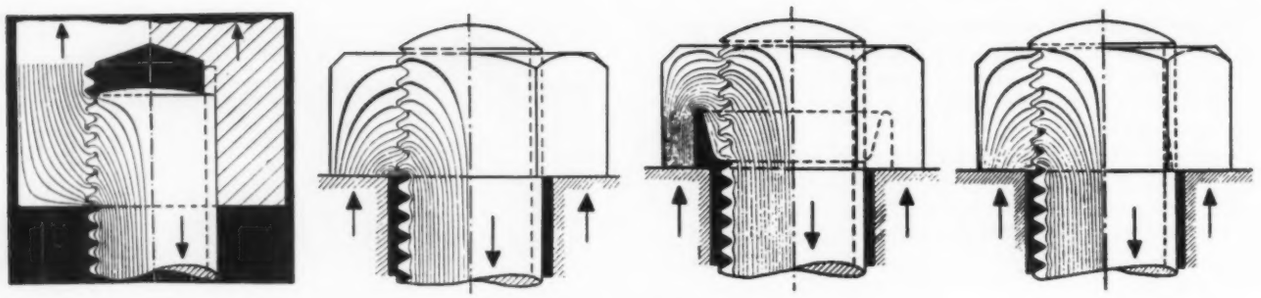

FIG. 8 FORCES IN BOLTS AND NUTS

(From left to right: *a*, Force-flow lines in a screw stud. *b*, Non-uniform loading in a screw stud with nut. *c*, Nut with deep notch and *d*, Nut with conical hole, showing more uniform loading than in *c*.)

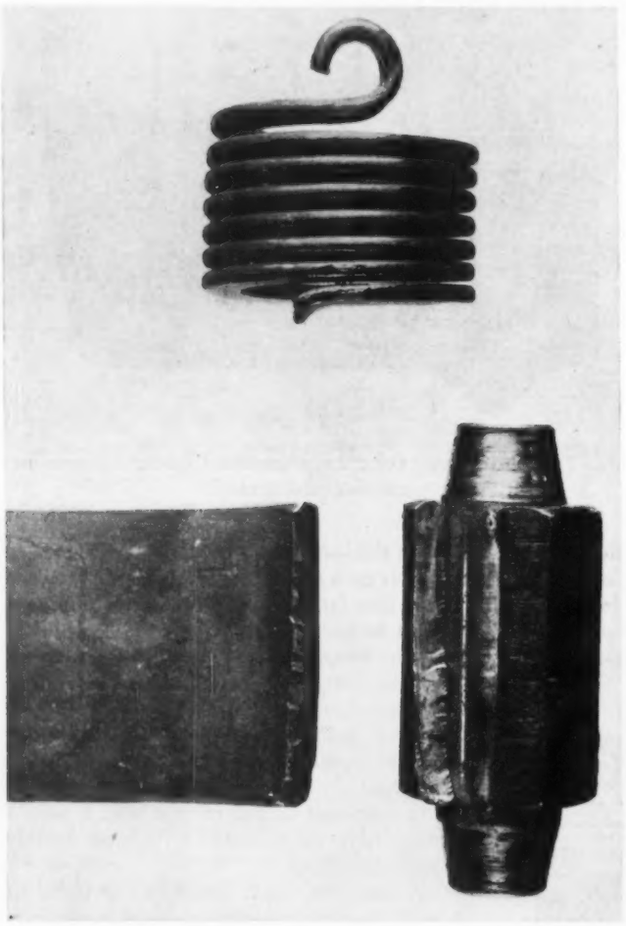

FIG. 9 TOP—FRACTURED TORSION SPRING

FIG. 10 BOTTOM—FRACTURED END OF MAIN LEAF OF AUTOMOBILE SPRING

nience, if not expense, is encountered by the failure of torsion springs at their end fastening. The type of spring shown in Fig. 9 is commonly used in the starting mechanism of automobile engines. The spring undergoes a cycle of stressing in torsion each time the mechanism is employed and therefore over a period of time many cycles of alternating stress are imposed.

The fastening of the spring restrains the spring at the ends and produces a combination of bending around the two principal axes along with the torsion and tension. The maximum stresses occur very close to the end loop and often produce fracture of the spring.

Fractures would be less common were the moment of inertia more nearly equal around the two principal axes, particularly near the ends where failures now occur. This could be accomplished readily by forging the end into more nearly a square instead of a rectangular cross-section.

Main Leaf of Automobile Spring. The end of the main leaf of an automobile spring is partially restrained from rotating freely at the shackle due to friction forces. When there is improper greasing, the end bending moments may become very large. Fractures in the main leaf just away from the end loop have resulted from repeated bending stresses of this kind. In the photograph, Fig. 10, may be seen the two characteristic regions of the fatigue break.

An obvious remedy for such spring failures would be to provide adequate lubrication. It must be appreciated that sufficiently frequent application of grease is rarely provided.

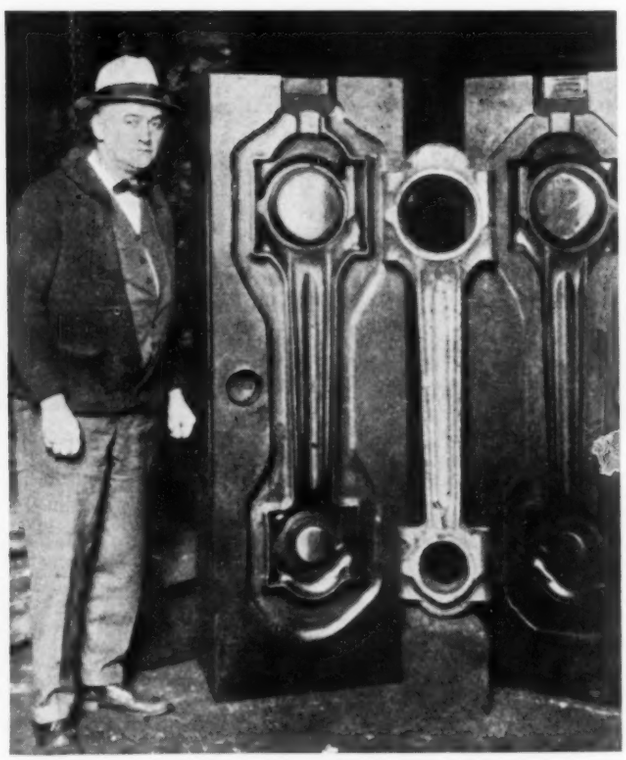

FIG. 11 CONNECTING ROD IN WHICH FRACTURE SHOWN IN FIG. 12 OCCURRED

Either a stiffening rib or more thickness might be resorted to in order that failures of the main leaf of a spring near the knuckle may be minimized.

The similarity in the type of failure of this and the previously described spring will be readily observed.

Connecting Rod. The inertia forces in a large connecting rod, shown in Figs. 11 and 12 have caused variable stresses during each cycle of operation of the engine. Forces imposed on the connecting rod by the periodic explosion in the cylinder also induce fluctuating stresses but for heavy rods the forces causing lateral bending must be properly considered. The cross-section is an I-beam but apparently is too light to withstand the fatigue action. An analysis of the stresses in such a problem can quite readily be made with only a very moderate amount of experimental information given. The solution is essentially one based on theoretical considerations.

Crane Hook. The stresses on the inner surface of a curved bar such as a crane hook are appreciably higher than might be expected from the elementary theory of strength of materials. Fig. 13 shows the fracture which resulted from repeated loadings of a foundry crane hook[3] after some five months of service. It seems quite evident that the "old crack" region is what is commonly called the region of slow-forming fatigue cracks. The source report given on this fracture attempts to attack the problem on a strictly metallographic basis.

A T-shaped cross-section may be used to advantage in cases of curved bars, especially when they are under fatigue conditions.

STRESS ANALYSIS INADEQUATE

Heads of Drums. The heads of drums subjected to high internal pressures have failed by ripping at the knuckle radius. Fig. 14, although a photograph of a test drum with heads and side sheets 2 in. thick, is representative of failures due to faulty design.

Bending in addition to axial and hoop stresses at the sharp knuckle radius has led to a change in head design in favor of the so-called "elliptical" form.[4]

The fractured surface suggests brittleness rather than the ductile mild carbon steel of which the drum is made. It is well known, however, that the complex stress condition which obtains, in which the shearing stresses are relatively low although there exist large principal stresses, produces separation rather than sliding. The condition in this instance is precisely that present in the inner region of the tensile specimen at the section of fracture.

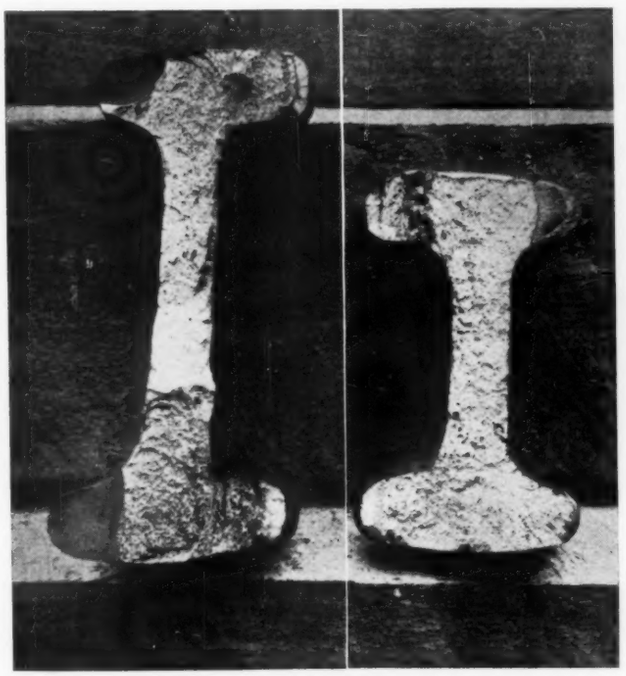

FIG. 12 FRACTURED CONNECTING ROD

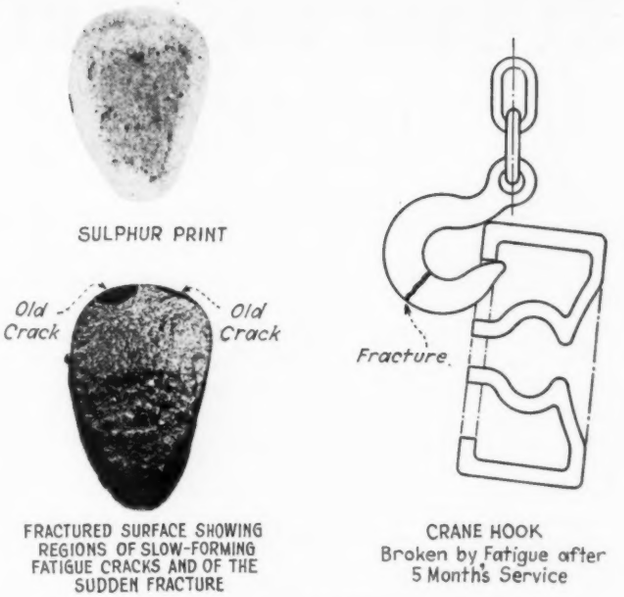
SULPHUR PRINT
Old Crack
Old Crack
FRACTURED SURFACE SHOWING REGIONS OF SLOW-FORMING FATIGUE CRACKS AND OF THE SUDDEN FRACTURE
Fracture
CRANE HOOK
Broken by Fatigue after 5 Months Service

FIG. 13 CRANE HOOK BROKEN BY FATIGUE

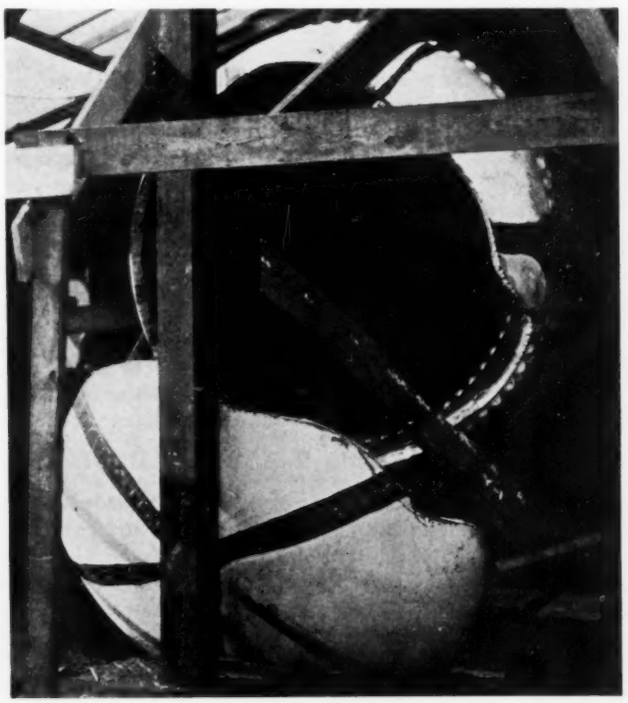

FIG. 14 FAILURE OF PRESSURE-DRUM HEAD

[3] British Engine Boiler and Electrical Insurance Co., Ltd., Technical Report for 1930–1931, p. 18.

[4] "The State of Stress in Full Heads of Pressure Vessels," W. M. Coates, Trans. A.S.M.E., vol. 52 (1), 1930, APM-52-12, p. 117.

STEAM RESEARCH *at the* BUREAU *of* STANDARDS

By N. S. OSBORNE, H. F. STIMSON, AND D. C. GINNINGS

NATIONAL BUREAU OF STANDARDS, WASHINGTON, D. C.

ALTHOUGH the calorimetric measurements made up to the time of the last annual progress report[1] covered the range undertaken, and served at that time to indicate changes to be anticipated in the current steam tables, the work was still incomplete for the vapor. Further work on this part has now been done to round out and verify the entire series of results. The additional measurements made during the past year were of the Gamma type, which measures the energy to produce and remove from the calorimeter a unit mass of saturated vapor.

Completion of a detailed report has been postponed pending further experiments near the critical region. It has, however, been possible to assemble the experimental results into a table of properties of saturated steam, covering nearly the entire range of the two-phase boundary.

As prepared for presentation at the International Conference of 1934, this table contained values of the enthalpy of saturated liquid and vapor. It also contained values of the specific volume of the saturated vapor, consistent, through the Clapeyron relation, with the calorimetric data and with the vapor-pressure derivatives given by the formulation[2] previously published. The substance of this table in the range 0 to 370 C is given in this paper in Table 1 as a summary of the adjusted experimental results.

Only a brief statement will be given defining the contents of this table with regard to source and thermodynamic significance. A more complete analysis of theory is given in previous reports.[3] The values, designated as Alpha in column 2, are the smoothed and adjusted values of the change, reckoned from 0 C to t C of the quantity $H - L\frac{u}{u' - u}$. The adjustment takes into account the calorimetric measurements made with an earlier calorimeter in the interval 0 to 270 C, and published in 1930,[4] as well as a new series of measurements which has been made in a completely new calorimeter suitable for higher temperatures and pressures. The range of this new series, extending from 100 C to 370 C, overlaps the previous series by 170 deg, and is therefore a repetition of those measurements. The two calorimeters employed were similar in general principle, but very different in details of design and in technique of manipulation. The values from the two series, where they overlap, although not identical, agree within the estimated accuracy of the earlier results. This confirmation of results in a range of temperature below that for which the later calorimeter was designed is an important check on the reliability of the adjusted values of the entire group of data resulting from the two investigations.

The values in column 3 are the smoothed and adjusted values of the quantity $L + L\frac{u}{u' - u}$, designated as Gamma. The earlier measurements of this quantity in the interval 50 to 270 C published in 1930 and 1932, are also included in this adjustment. The new series extends from 100 to 370 C. The experimental technique in the new measurements was superior, particularly in regard to control during the withdrawal of vapor. Greater variations in method were also employed as a test for errors from such possible sources as heat leaks, temperature gradients, and carry-over of liquid drops in the vapor.

Column 4 contains values of the quantity $L\frac{u}{u' - u}$, designated as Beta, which is complementary to both Alpha and Gamma in the evaluation of the latent heat and of the enthalpy of the liquid and vapor. A series of values of Beta has been observed calorimetrically in the range from 100 to 370 C. The accord shown between these observed values and those calculated from the liquid specific-volume data of Smith and Keyes[5] justifies, in this assembly of results, use of the calculated values as representing sufficiently well the smoothed experimental values.

The enthalpy of the saturated liquid and saturated vapor, and the latent heat, as given in columns 5, 6, and 7, are obtained by direct algebraic combination of the numerical values of Alpha, Beta, and Gamma.

The values of specific volume u' of the vapor given in column 8 are computed from the corresponding values of Gamma, using the values of dP/dt given by the N.B.S. formula[2] of 1934 in the equation

$$u' = \frac{\gamma dt}{T dP}$$

which is a corollary of the Clapeyron equation.

The table is thus thermodynamically consistent with the N.B.S. formulation of vapor pressure and the M.I.T. formulation of the specific volume of saturated liquid, with the reservation, however, that the correlation is subject to any errors in the scale of temperature and scale of vapor pressure. Small changes in the tabulated values may result from the revision of these scales, but these probably would not be of importance to working steam tables.

Other small changes may result from measurements still in progress in the near vicinity of the critical region. For the purpose of investigating the possible effect of liquid entrained in the steam and carried over in the evaporation experiments,

[1] MECHANICAL ENGINEERING, February, 1934, pp. 94–95.

[2] "A Formula and Tables for the Pressure of Saturated Water Vapor in the Range 0 to 374° C.," by Osborne and Meyers, B.S. *Journal of Research*, vol. 13, 1934, RP 691, p. 1.

[3] Trans. A.S.M.E., vol. 52, 1930, paper FSP-52-29, p. 221. B.S. *Journal of Research*, vol. 4, 1930, RP 168, p. 609.

[4] Trans. A.S.M.E., vol. 52, 1930, paper FSP-52-28, p. 191. B.S. *Journal of Research*, vol. 5, 1930, RP 209, p. 411.

Contributed by the Special Research Committee on Thermal Properties of Steam and presented at the Annual Meeting, New York, N. Y., December 3–7, 1934, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

Publication approved by the Director of the National Bureau of Standards of the U. S. Department of Commerce.

[5] Proc. Am. Acad. Arts and Sci., vol. 69, 1934, p. 285.

TABLE 1 PROPERTIES OF SATURATED STEAM

(Adjusted Experimental Results, National Bureau of Standards, December 5, 1934)

Temp. t deg C	Alpha $H-\frac{Lu}{u'-u}$ int. j/g	Gamma $L+\frac{Lu}{u'-u}$ int. j/g	Beta $\frac{Lu}{u'-u}$ int. j/g	Enthalpy liquid H int. j/g	Enthalpy vapor H' int. j/g	Latent heat L int. j/g	Vapor volume u' m^3/kg
0	0.00	2497.78[a]	0.01	0.00	2497.77[a]	2497.77[a]	206.43[a]
10	42.01	2475.23[a]	0.02	42.02	2517.23[a]	2475.21[a]	106.50[a]
20	83.80	2452.42[a]	0.04	83.83	2536.21[a]	2452.38[a]	57.872[a]
30	125.53	2429.34[a]	0.07	125.59	2554.86[a]	2429.27[a]	32.942[a]
40	167.23	2405.97[a]	0.12	167.34	2573.19[a]	2405.85[a]	19.550[a]
50	208.92	2382.30	0.20	209.11	2591.21	2382.10	12.047
60	250.61	2358.28	0.31	250.91	2608.88	2357.97	7.6788
70	292.29	2333.88	0.47	292.75	2626.16	2333.41	5.0464
80	333.98	2309.06	0.70	334.67	2643.03	2308.36	3.4094
90	375.66	2283.79	1.00	376.65	2659.44	2282.79	2.3617
100	417.36	2258.00	1.41	418.76	2675.35	2256.59	1.6733
110	459.05	2231.63	1.94	460.98	2690.67	2229.69	1.2103
120	500.76	2204.67	2.62	503.37	2705.42	2202.05	0.89179
130	542.46	2177.00	3.48	545.93	2719.45	2173.52	0.66831
140	584.16	2148.58	4.56	588.71	2732.73	2144.02	0.50861
150	625.86	2119.29	5.89	631.74	2745.14	2113.40	0.39250
160	667.54	2089.11	7.50	675.03	2756.64	2081.61	0.30678
170	709.21	2057.91	9.45	718.65	2767.11	2048.46	0.24256
180	750.84	2025.61	11.78	762.61	2776.44	2013.83	0.19380
190	792.45	1992.09	14.55	806.99	2784.53	1977.54	0.15631
200	834.02	1957.24	17.80	851.81	2791.25	1939.44	0.12716
210	875.55	1920.97	21.61	897.15	2796.51	1899.36	0.10425
220	917.03	1883.11	26.04	943.06	2800.13	1857.07	0.08606
230	958.47	1843.52	31.18	989.64	2801.98	1812.34	0.071470
240	999.85	1802.04	37.12	1036.96	2801.88	1764.92	0.059674
250	1041.19	1758.51	43.96	1085.14	2799.69	1714.55	0.050054
260	1082.46	1712.68	51.83	1134.28	2795.13	1660.85	0.042145
270	1123.67	1664.34	60.90	1184.56	2788.00	1603.44	0.035593
280	1164.81	1613.16	71.33	1236.13	2777.96	1541.83	0.030124
290	1205.88	1558.77	83.38	1289.25	2764.64	1475.39	0.025527
300	1246.88	1500.69	97.36	1344.23	2747.56	1403.33	0.021634
310	1287.80	1438.20	113.68	1401.47	2725.99	1324.52	0.018312
320	1328.64	1370.26	132.93	1461.56	2698.89	1237.33	0.015454
330	1369.39	1295.31	156.01	1525.39	2664.69	1139.30	0.012968
340	1410.06	1210.71	184.36	1594.41	2620.76	1026.35	0.010776
350	1450.63	1111.86	220.74	1671.36	2562.48	891.12	0.008798
360	1491.12	988.8	271.61	1762.72	2479.9	717.2	0.006941
370	1531.51	801.2	362.96	1894.46	2332.7	438.2	0.004949

[a] Extrapolated.

special tests are being made, using a wide range of rates of evaporation.

Fig. 1 shows graphically the extent of the calorimetric survey of saturated steam. The dotted portions indicate where extrapolation is necessary to complete the boundary of the saturation region.

There still remains to be done some "clearing up" of the data at low pressures. Two problems of this kind are demanding attention. The first is a more precise survey of the heat capacity of liquid water between 0 and 100 C. Data in this region have not been in complete accord, and reliable values are important for use as calorimetric standards. Plans for this work are being studied. Special apparatus will be required.

A second problem is the completion of the series of latent-heat measurements in the range 0 to 50 C. This will also require special apparatus.

Except for these few items requiring further investigation, but not immediately vital to working steam tables, the part of the steam research assigned to the National Bureau of Standards has been completed. The sponsors of this work have been patient and generous, and deserve the gratitude of the engineering profession for making possible this contribution to steam data.

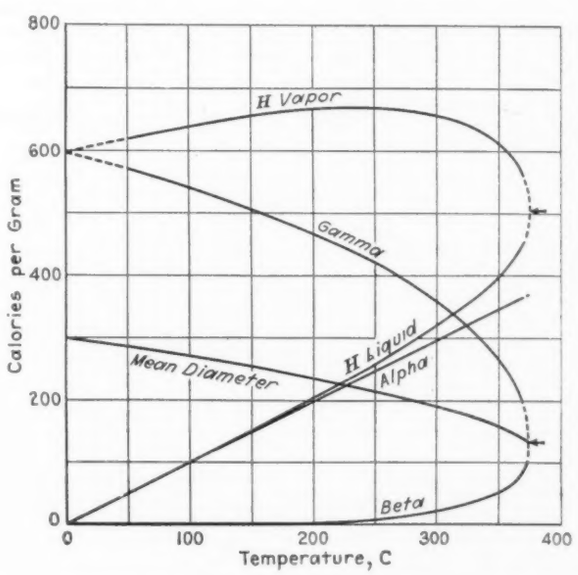

FIG. 1 EXTENT OF CALORIMETRIC SURVEY OF SATURATED STEAM

The EQUATION *of* STATE *for* SUPERHEATED STEAM

And Some Comments on Derived Quantities

By FREDERICK G. KEYES, LEIGHTON B. SMITH, AND HAROLD T. GERRY

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

DURING the year the equation of state for steam based on the M.I.T. volume data has been reconsidered and a modification introduced. The general form of the equation remains the same, but the arrangement of the terms into factors was changed slightly. Volumes computed with the modified equation show about as good agreement with the 1905 observations of Knoblauch, Linde, and Klebe as before.[1] In the case of other quantities H, C_p and the Joule-Thomson effect the computations are in good accord with observational material. The equation of state is as follows:

$$p = \frac{RT}{v - B}; \quad T = 273.16 + t°\text{C}; \quad \tau \equiv T^{-1}$$

$$R = 4.55504$$

$$B = B_{01} + B^{2}{}_{01}g_1(\tau)\tau p + B^{4}{}_{01}g_2(\tau)\tau^3 p^3 - B^{13}{}_{01}g_3(\tau)\tau^{12}p^{12} \quad [1]$$

$$B_{01} = 1.89 - 2641.62\ \tau \times 10^{80870\tau^2}$$
$$g_1(\tau) = 82.546\tau - 1.6246 \times 10^5\tau^2$$
$$g_2(\tau) = 0.21828 - 1.2697 \times 10^6\tau^2$$
$$g_3(\tau) = 3.635 \times 10^{-4} - 6.768 \times 10^{64}\tau^{24}$$

Pressures are in international atmospheres. Volumes are in cubic centimeters per gram of steam.

THE ENTHALPY EQUATION OF SATURATED AND SUPERHEATED STEAM

The equation for H, the enthalpy, has been modified on the basis of new information[2] on C_{p0}, the heat capacity that steam would exhibit at zero pressure.

The C_{p0} values are derived from measurements on the band spectrum of water vapor which is now fairly complete due to recent work by Mecke,[3] Baumann and Mecke,[4] and Freudenberg and Mecke.[5] The computations have not been verified but the values given from room temperature to 600 C are represented with substantial accuracy by the following formula:

$$C_{p0} = 1.798 + 0.00148\ \frac{T^2}{2000 + T}\ (\text{Int. joules}) \quad \ldots\ldots [2]$$

Using the value of the enthalpy (in joules) of steam at 100 deg determined by Osborne, Stimson, and Fioch, the value of h_0 (2502.4) was computed in the following equation:

$$H = h_0 + \int_{273.16}^{T} C_{p0}\,dT + \int_0^p \left(\frac{\partial B\tau}{\partial \tau}\right)_p dp \quad \ldots\ldots [3]$$

The second integral in the equation may be determined from the equation for B. The computed values and the observed values for saturated steam are given in Table 1.

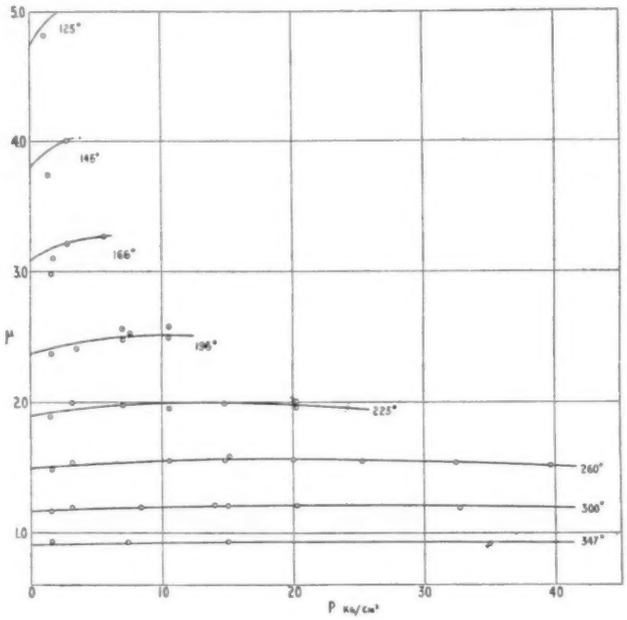

FIG. 1

TABLE 1 ENTHALPY OF SATURATED STEAM

(International Joules)

t deg C	Computed equation of state, M.I.T.	U. S. Bureau of Standards
0	2502.0	2497.8
50	2592.0	2591.2
100	2675.3	2675.3
150	2745.2	2745.1
200	2790.8	2791.2
250	2799.2	2799.7
300	2747.3	2747.6
350	2562.7	2562.5

THE JOULE-THOMSON VALUES

The diagram, Fig. 1, corresponding to Fig. 5 of last year's report, shows improved agreement with the observed values of dT/dp or μ obtained by Davis and Kleinschmidt. The improved correspondence is due to new low-pressure data on steam obtained by S. C. Collins, using the new calorimeter which measures $\left(\frac{\partial H}{\partial p}\right)_T$ and $\frac{dT}{dp}$ in the same apparatus. Using the equation of state, Equation [1], the following relation may be obtained:

(*Continued on page 176*)

[1] MECHANICAL ENGINEERING, February, 1934, pp. 87–92, Table 1.
[2] A. R. Gordan, *Jour. Chem. Phys.*, vol. 2, 1934, p. 65.
[3] Mecke, *Zeit. Phys.*, vol. 81, 1933, p. 313.
[4] Baumann and Mecke, Ibid., vol. 81, 1933, p. 445.
[5] Freudenberg and Mecke, Ibid., vol. 81, 1933, p. 465.

Contribution No. 345 from the Research Laboratory of Physical Chemistry, Massachusetts Institute of Technology, Cambridge, Mass.

Recent Developments in STEAM TURBINES

By C. RICHARD SODERBERG

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IT IS SOMEWHAT difficult to speak of the probable trends at the present time in the central-station industry, as far as turbines are concerned, because practically none are bought. It is not generally realized that it is more than twenty-seven months since the last central-station turbine was purchased. However, the very reason for this inactivity—hesitation in applying capital to new undertakings—indicates that when new developments are once again started, they will be judged very critically from the particular point of view of capital investments. To us in the power-manufacturing industry, therefore, the most important trend seems to be the determination on the part of our prospective customers to obtain improvements in their heat and power cycles with a minimum of capital outlay.

This trend has not retarded the advance toward higher efficiencies of power generation, but the direction of the development has been altered. It is not so long ago that we looked for greater concentration in the form of larger stations and units. This development will probably not materialize; there is every reason to believe that many future developments will be in the form of smaller units distributed over the load areas. Interstage reheating as a means for promoting the use of higher inlet pressures was also regarded as an obvious channel of development a few years ago. Today, this tendency is definitely a thing of the past, at least in connection with conventional types of boilers.

The combination of power and steam generation for heating purposes and process work is perhaps the most significant of the recent trends. In the condensing cycle, even in its most ideal form, more than 50 per cent of the available energy is dissipated by the cooling water. The only means of recovering this waste is to combine power generation with heat generation. It is certain that broad-scale planning for the preservation of fuel resources, which is certain to come, will concentrate on developments along this line. It is not always realized that heating and industrial demands for process steam make available a natural source of power which is much more significant than all of our possible hydroelectric developments.

The principal technical advances in the economy of power generation must be obtained through advances in the inlet pressure and temperature. Increases in the pressure for the usual condensing cycle are limited by the amount of moisture that may be permitted in the turbine exhaust. Figs. 1 and 2 illustrate this condition for turbine efficiencies of 80 and 85 per cent, respectively. Limiting the wetness to 12 per cent, it is apparent that an inlet pressure of 1200 lb per sq in. demands an inlet temperature of from 800 to 1000 F. Higher pressures will involve reheating.

This situation presents a real incentive for advances in the direction of higher temperatures, and there is no exaggeration in saying that this is our most important development problem. Practically everything done to the steam turbine during latter years has been directed to the problem of making advances in temperature possible.

At the present time we regard 825 F as a practical steam temperature for all steam pressures of interest and for all sizes of steam turbines. We are prepared to extend this temperature to 900 F for machines operating at 3600 rpm and believe that 1000 F may eventually become practical. The turbine development has thus kept a fairly even pace with boiler and superheater developments.

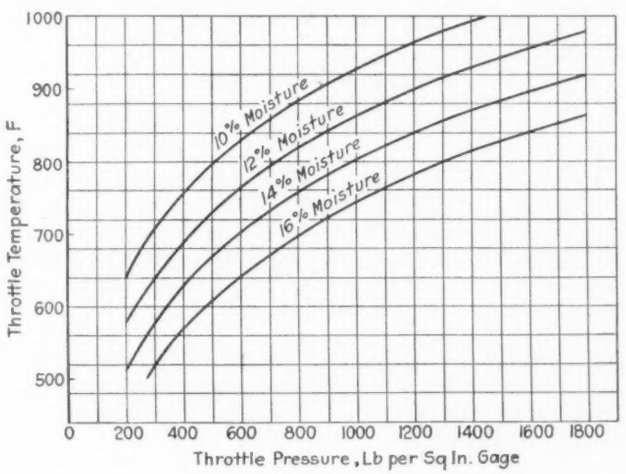


FIG. 1 MOISTURE CONTENT IN EXHAUST STEAM WITH 29-IN. VACUUM AND 80 PER CENT CYCLE EFFICIENCY

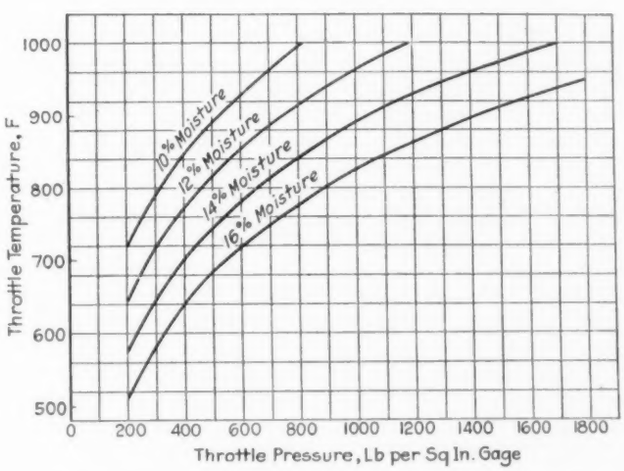


FIG. 2 MOISTURE CONTENT IN EXHAUST STEAM WITH 29-IN. VACUUM AND 85 PER CENT CYCLE EFFICIENCY

A paper presented before the Philadelphia Section, Philadelphia, Pa., November 27, 1934, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

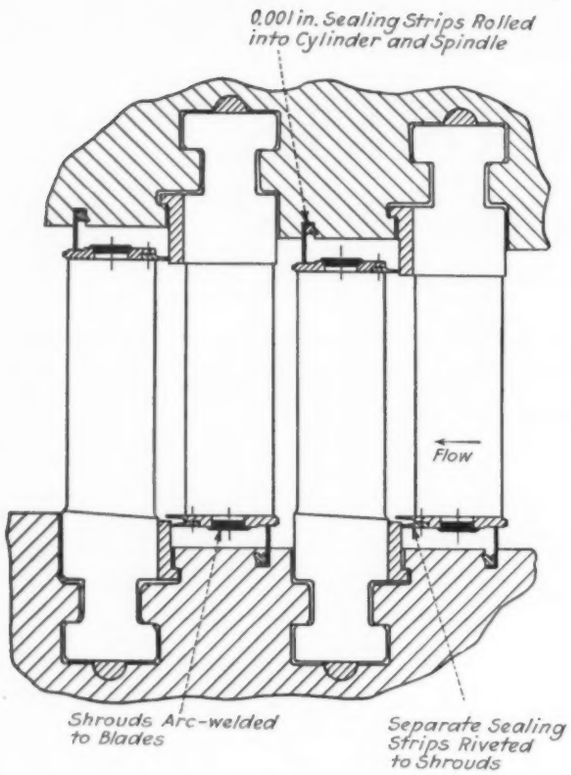

0.001 in. Sealing Strips Rolled into Cylinder and Spindle
Flow
Shrouds Arc-welded to Blades
Separate Sealing Strips Riveted to Shrouds

FIG. 3 AXIAL CLEARANCE REACTION BLADING

In the past the introduction of higher inlet steam conditions has always involved the scrapping of existing turbine equipment and few innovations are of sufficient merit to justify this. The method of superimposing new high-pressure equipment upon existing low-pressure equipment represents one of the most important innovations in power-plant development of recent years. It seems to be the only method whereby technical advances in steam engineering can be applied without prohibitive capital investment.

AN EXAMPLE

The following is a typical example of this method. A power station constructed fifteen years ago consists of two 15,000-kw turbines operating under 175 lb per sq in., 100 F superheat, and 28.5 in vacuum steam conditions. The heat rate for the station is 23,000 Btu per kwhr. The station equipment is in fairly good condition, requiring only a moderate amount of repair to blading. The proposed solution is to remove the old boiler equipment and put in its place steam-generating equipment for higher inlet steam conditions. An alternative method is to leave the old boiler equipment for reserve in emergency. The steam is passed through new back-pressure turbines, exhausting into the old turbines at pressures and temperatures near the old steam conditions. The old low-pressure turbines are not as efficient as more up-to-date equipment, but they are usually generous in size for the steam flow and the blade speeds are low, permitting a fairly high moisture content. A little investigation will show that the new steam conditions may be selected at 1250 lb per sq in. and 900 F. Naturally, the new equipment will be introduced with an appropriate rearrangement of feed heating. Assuming a final feed temperature of 375 F it will be found that the boiler flow is 585,000 lb per hr, when the old units carry their rated load, 30,000 kw. The superimposed high-pressure unit then carries 28,500 kw and the heat rate for the station will be about 12,500 Btu per kwhr, reducing fuel costs to 55 per cent of those of the old plant. Operation at partial loads may be still further improved if the new turbine is equipped with multivalve control and the old turbines are of the single or two-valve type. In many instances, the new equipment does not require additional floor space.

In the example cited, the capacity of the station was changed from 30,000 to 58,500 kw and the heat rate from 23,000 to 12,500 Btu per kwhr. The cost of the added plant capacity will vary greatly with the individual conditions, but usually it will be lower than the unit cost of the original equipment.

In view of this development, the 3600-rpm back-pressure turbine is bound to become one of the most important types of future central-station turbines. There is no definite limit of the maximum possible capacity of this type of turbine and we have already projected such units for steam flows in excess of 1,000,000 lb per hr. The limit in capacity will be set by the generator. Present developments have been carried up to about 50,000 kva.

Naturally, this method of plant extension is applicable only when there is available suitable low-pressure equipment which may be retained. In all other cases, new plant construction involves the use of condensing turbines of the usual type which will always retain its importance to the central-station industry. These machines may now be built in capacities up to about 100,000 kw in single-cylinder units at 1800 rpm. Two-cylinder tandem construction permits units of 200,000 kw for which a single generator can be constructed. We do not expect to be called upon to build larger units than this within the predictable future.

The most notable advances in the size of individual units have been made in the 3600-rpm class, which is particularly important in view of its adaptability to high inlet temperatures. In the single-cylinder type we can now build units of 17,500 kw capacity. The two-cylinder tandem types may be constructed for 35,000 kw. This is also the present comfortable limit for 3600-rpm generators, although still larger generators probably can be built.

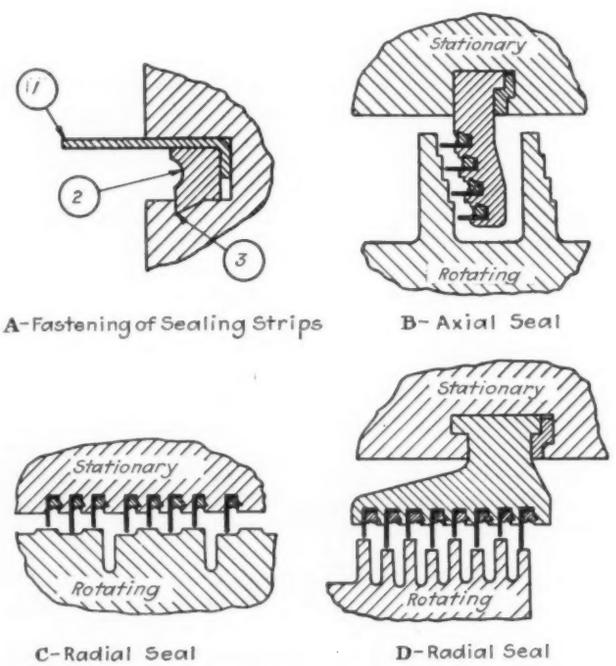


FIG. 4 SEALING DETAILS FOR GLANDS AND DUMMIES

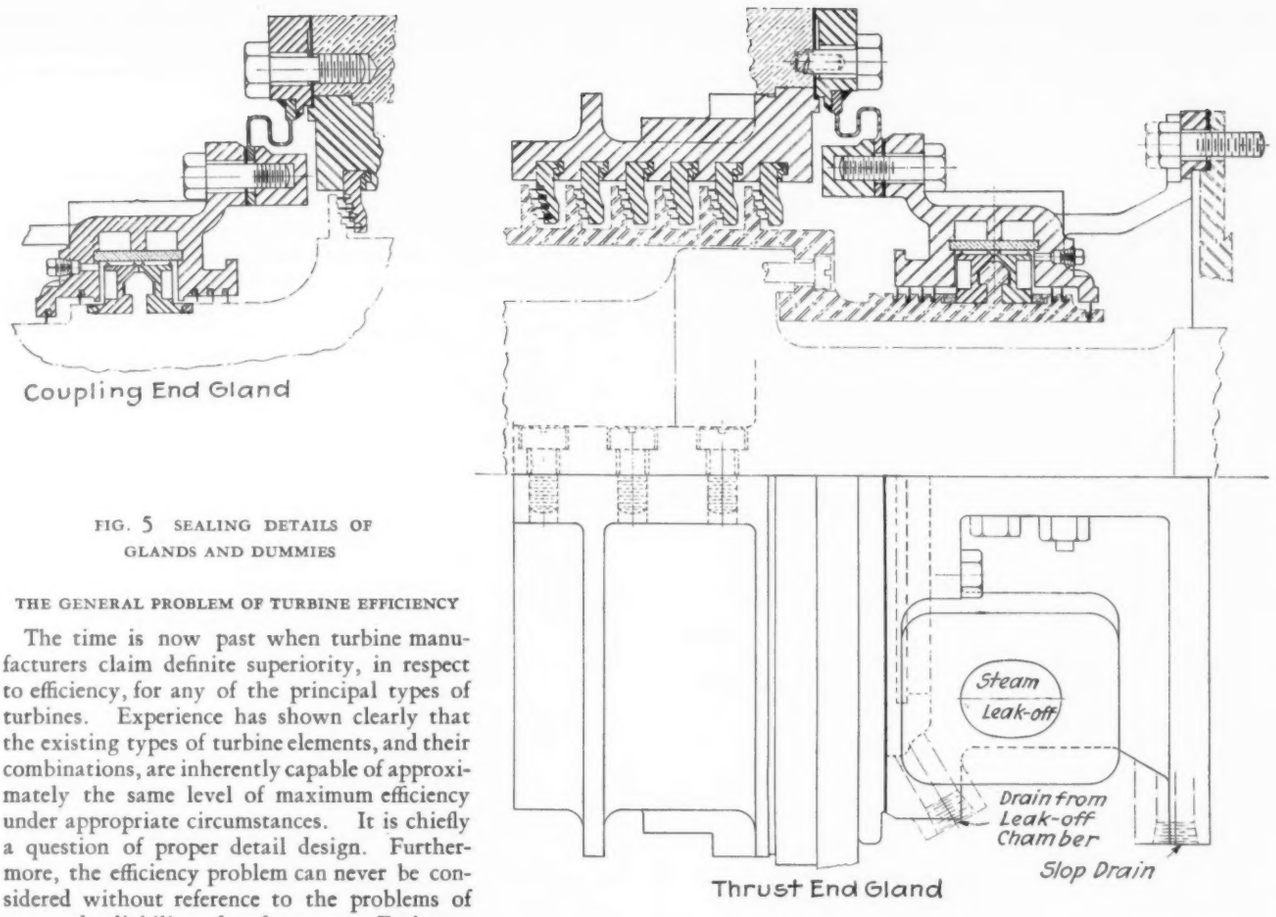


FIG. 5 SEALING DETAILS OF GLANDS AND DUMMIES

THE GENERAL PROBLEM OF TURBINE EFFICIENCY

The time is now past when turbine manufacturers claim definite superiority, in respect to efficiency, for any of the principal types of turbines. Experience has shown clearly that the existing types of turbine elements, and their combinations, are inherently capable of approximately the same level of maximum efficiency under appropriate circumstances. It is chiefly a question of proper detail design. Furthermore, the efficiency problem can never be considered without reference to the problems of cost and reliability of performance. Each turbine design is thus a compromise between all of these important factors.

The basic efficiency of a reaction stage of great blade heights can probably be brought to about 95 per cent. The discrepancy between this value and the present values of turbine efficiency of from 70 to 85 per cent is often a surprise to the purchaser of steam turbines. The principal problem of the turbine designer is to reduce the gap between these figures. No short cuts are of any avail in this connection; it is principally a question of making a patient study of a multitude of small details.

The principal sources of loss which cause the discrepancy between the ideal and actual efficiencies are:

(*a*) Losses due to the impracticability of having every stage operate at its maximum efficiency.
(*b*) Leakage of steam in the stage.
(*c*) Leakage of steam in glands and balancing pistons.
(*d*) End effects (and leakage disturbances) preventing ideal flow.
(*e*) Disturbances due to mechanical details, such as lashing wire and reinforcements of blades.
(*f*) Leaving and exhaust loss.
(*g*) Losses due to the presence of moisture in the low-pressure region.
(*h*) Mechanical losses due to friction in the steam path, in bearings, etc.

All of these are important, but not all are equally susceptible to improvement. The first item is chiefly one of number of stages and general arrangement of blade path. It is the one point on which the designer's patience and perseverance is most taxed, particularly for multivalve turbines.

The leakage problem in the individual stages and at the ends of the cylinders (items *b* and *c*) is one of the greatest single items in the list of losses. Variations in turbine designs generally represent variations in leakage details. No other class of detail more forcibly affects the reliability of a turbine.

The clearances which are used in modern turbines are necessarily very close, and the possibility of mechanical contact between rotating and stationary parts must be admitted. It is necessary to arrange the sealing details in such a manner, therefore, that the contact has no other consequences than a possible enlargement of the clearance. When all such adjustments have taken place throughout a turbine, it must still give its guaranteed efficiency.

Experience has shown that these requirements can be met only by thin sealing strips made of special materials which will confine the effects of a contact to the strip itself. Figs. 3, 4, and 5 show examples of how these problems have been solved in some late designs.

The general problems of flow disturbances in the blade path (items *d*, *e*, and *f*) represent another extremely important group of subjects. Perhaps the most important contribution to this subject of the last two or three years is the development of laboratory methods for investigating the various details of flow problems.

A static reaction tester which has now been in continuous use for some time, measures accurately the reaction for a blade passage when air is flowing through it. With this apparatus, it has already been possible to establish a blade shape consider-

ably more efficient than older types. The losses due to lashing wires, the efficiency of various sealing arrangements, the influence of surface finish and polish, and many other similar problems have already been investigated. Another apparatus

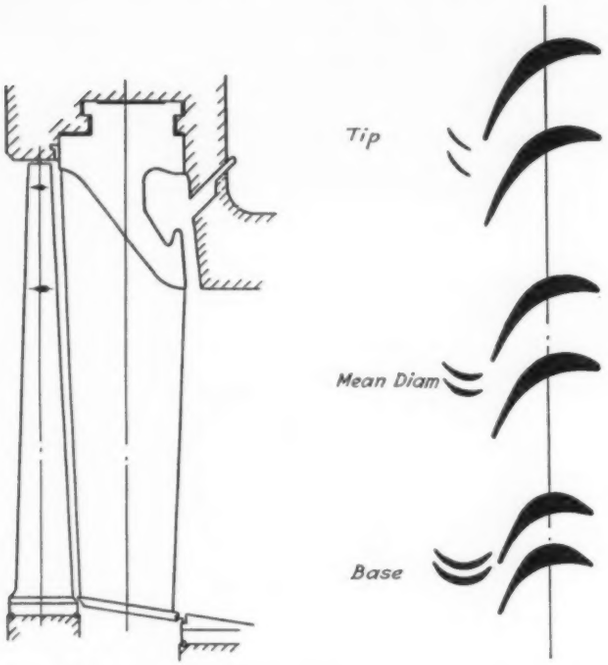


FIG. 6 NEW DESIGN OF STATIONARY LOW-PRESSURE BLADING

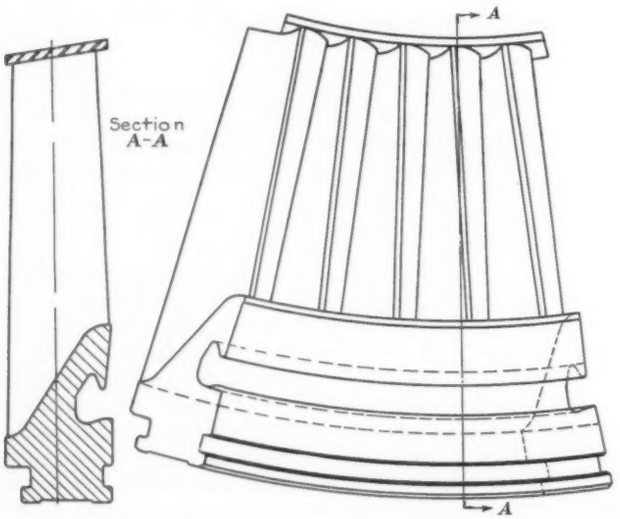


FIG. 7 NEW DESIGN OF STATIONARY REACTION BLADING

of the same type measures the combined performance of nozzles and blades.

LEAVING AND MOISTURE LOSSES

The leaving loss is one of the most important items for condensing turbines, but its magnitude is one of the fundamental quantities which can be influenced chiefly by the size of the last blade annulus. There are other similar losses beyond the last annulus, however, which can be reduced by intelligent design. Laboratory equipment is being used to study this problem and has already given very important results in establishing satisfactory proportions and shapes of exhausts of low-pressure cylinders of turbines. Air is pumped through the exhaust to simulate the flow of steam and pressures and velocities are carefully explored.

The losses due to moisture in the exhaust have also been subjected to study during the last few years. The true importance of this loss is beginning to be appreciated. It seems fairly certain that for the very large peripheral speeds now in use on large condensing turbines, the loss due to moisture is considerably greater than was formerly believed.

The principal components of the mechanical losses occur in

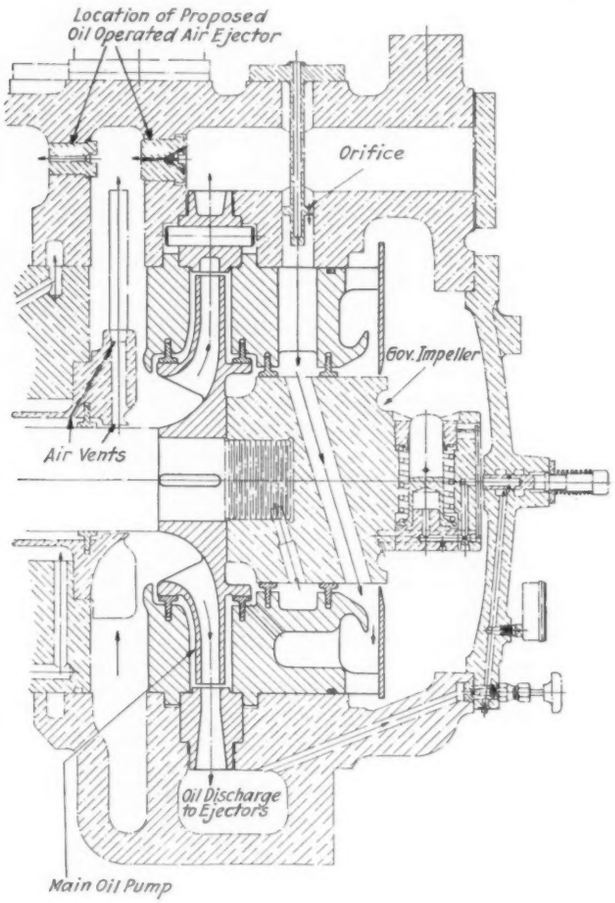


FIG. 8 FLUID-GOVERNOR OIL PUMP

the bearings, in water glands, and in oil pumps. Studies made on all of these elements have indicated methods for reducing them appreciably, even if the total magnitude of these items no longer is very great on the larger turbines.

The last rows of a condensing turbine present a particularly important aspect of the efficiency problem. The blade height in this type of blade is about one-third of the mean diameter, so that the conditions of flow change completely between the inside and the outside of the blade path. In addition, there is a very steep axial taper of the blade path.

PROBLEMS OF LONG BLADES

The fundamentals of the efficiency problem on these long blades have already been explored in the airfoil theory built up around airplane-wing and propeller design. The basic requirement in the design has been found to be constant circulation, the term "circulation" having its usual connotation in

airplane-wing design. In the turbine blade, this requirement is answered, in so far as practicable, by making the work done per unit length of the blade proportional to the square of the radius. This principle results in a rotating blade of the impulse type at the inner diameter, the standard reaction type at the mean diameter, and an airfoil section at the outside diameter. The pressure between the stationary and the rotating blade varies with the radius in the stage, but is constant along the radius before and after the stage. Stated somewhat loosely, it might be said that the principle of constant circulation corrects for the centrifugal force of the steam as it leaves the stationary row.

In order to reduce the influence of the taper of the blade path to a minimum, the new stationary blades have a curved contour of the boundary in the cylinder. The object of this modification from previous practice is to place the steepest angle of the taper at a point of minimum velocity, and to enable the steam to enter the rotating blading in a direction almost parallel with the axis of the turbine. Fig. 6 illustrates the new type of stationary blading.

NEW BLADE CONSTRUCTION

In order to check the correctness of these principles, a special apparatus was developed for exploring the flow in detail by impact tubes. Air is blown through a model, one-third size, of the stationary blading. Impact-tube readings are made in a sufficient number of points to map the magnitude and direction of the velocity, from which the efficiency can be calculated.

The new construction of the low-pressure blading demands stationary-blade structures of greater dimensions and more complicated shapes than those used heretofore. A considerable development has been carried out to obtain the best solution for this problem, the results of which are shown in Fig. 7.

THE CONTROL SYSTEM

One of the most difficult problems in the design of steam turbines is to give the control system the necessary sensitivity, freedom from oscillations, and reliability. This problem requires much specialized knowledge and skill and only a few of the more important aspects can be covered in the present paper.

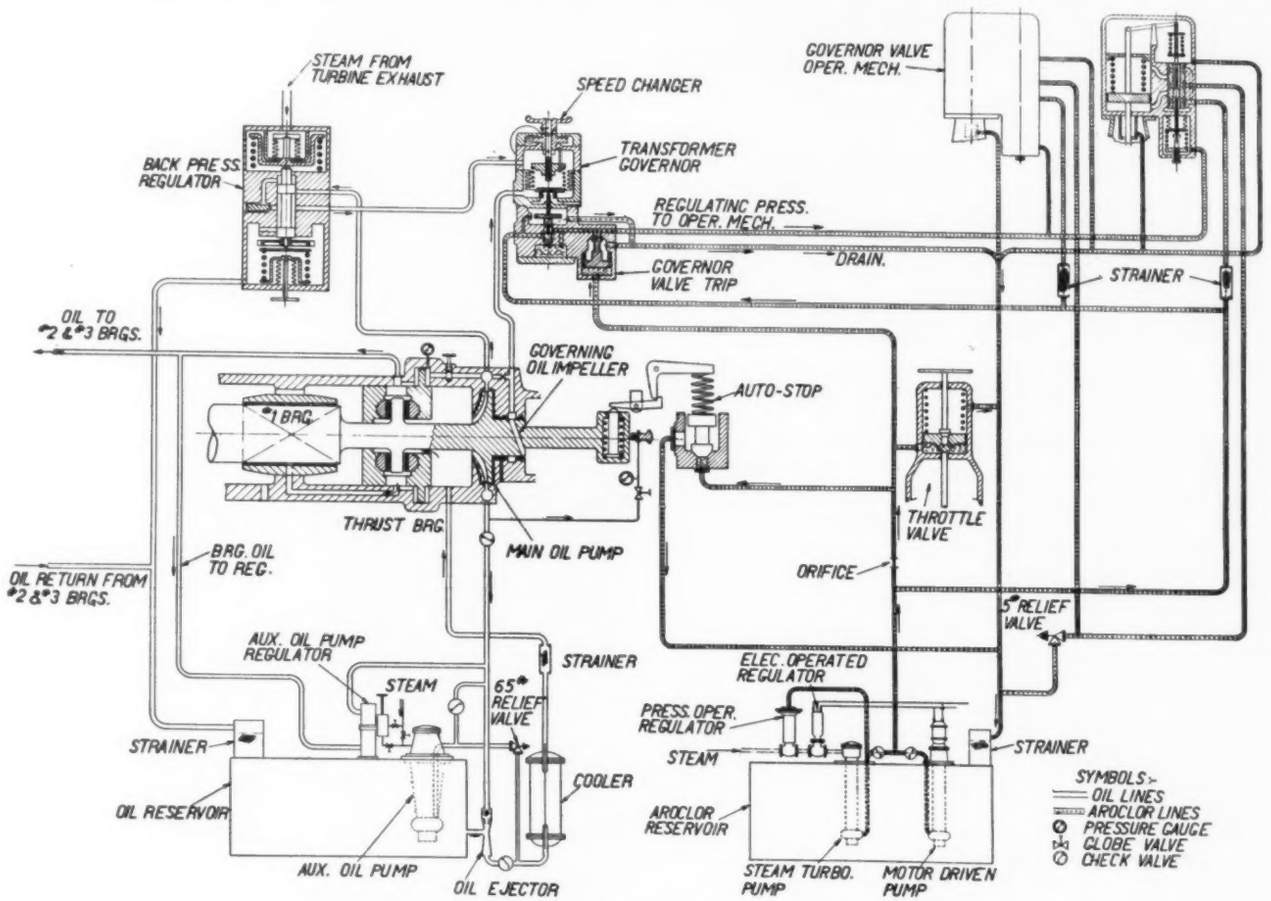


FIG. 9 TRANSFORMER GOVERNING SYSTEM USING TWO FLUIDS

The first fundamental control problem of steam turbines occurs in the conventional condensing installation, where the supply of steam at constant inlet properties is regulated for varying load to give constant, or nearly constant, speed. The problem occurs in this form only when the generator dominates its power system. If the turbines on the system are to share load changes in proportion to their capacity, the governors must have the same speed-variation characteristic from no load to full load. In many cases, all the turbines on a system are operated at their own best-efficiency-point load at a speed determined by the system frequency, the variations in load being taken on one or two machines whose governors are positioned by a sensitive frequency regulator.

The speed-responsive properties are always required for the synchronizing process, however, so that uniform demands are

FIG. 10 EROSION-TESTING MACHINE

made upon governor performance, regardless of the mode of operation.

A control system of this type may be divided into three groups of apparatus: The speed-responsive element, the valve operating gear, and the valves. An important addition to every control system is the overspeed governor.

One of the most common types of speed-responsive elements is still the flyball type. Since valve operating gears are almost universally of the hydraulic type, however, the fluid type of speed-responsive element (centrifugal oil pump) appears logical. This type has been used by Westinghouse for many years, all of the 3600-rpm industrial turbines having used it for the past ten years. During this time, it has been continuously perfected. It is probably true that the fluid type of governor has required more fundamental development than the flyball type, but now that this stage has been passed, it represents an ideal solution of this problem.

In the original form of the fluid governor, the centrifugal oil pump was placed on the shaft; this pump supplied the entire requirement of oil both for lubrication and governing, and its pressure served as the speed-responsive element. This system is satisfactory for the 3600-rpm industrial turbines where the lubricating and valve-operating oil requirements are small, but for the central-station machines, where large volumes of oil are required, a separate impeller functioning as speed-responsive element is used.

More recent developments have led to the construction, shown schematically in Fig. 8, in which the pressure-sensitive device is made as an adjunct to the main oil pump, which is still mounted on the main turbine shaft, but which no longer is required to have special pressure characteristics. This pressure-sensitive element has been made possible by the introduction of a special relay, the pressure transformer, through which the comparatively weak impulses from the impeller are magnified and reversed. The magnified impulses are transmitted to the relays of the valve operating mechanisms, arranged as servo motors. One important function of the transformer is the possibility of using separate fluids for governing and lubrication. In actual application, the speed-sensitive element and the transformer are both built into the thrust pedestal, so that the combination may be regarded as a specially sensitive speed device. While in the ordinary fluid governor a speed variation of ± 1 per cent causes a pressure variation of ± 2 lb per sq in. (for a mean impeller pressure of 100 lb per sq in.), this combination will deliver an impulse of about ± 16 lb per sq in. for the same speed change. The result is increased margin for relay friction in the valve operating mechanism.

The second type of control problem concerns the control of steam pressure at one or several points, in conjunction with speed governing. This leads to many varieties of control arrangements, particularly for bleeder turbines.

The fundamental principles are illustrated sufficiently well by considering the case of a back-pressure turbine with back-pressure control, in which the control system must at times respond to changes of back pressure, and at other times to changes of speed. It is then necessary to translate back-pressure impulses into the same currency as the speed changes. This is easily done by admitting oil at a pressure, dependent upon the back pressure, on the opposite side of the primary transformer diaphragm. Given the correct ratios of pressures, a rise in back pressure will be synonymous with a rise in speed, that is, both events will cause the governor valve to close.

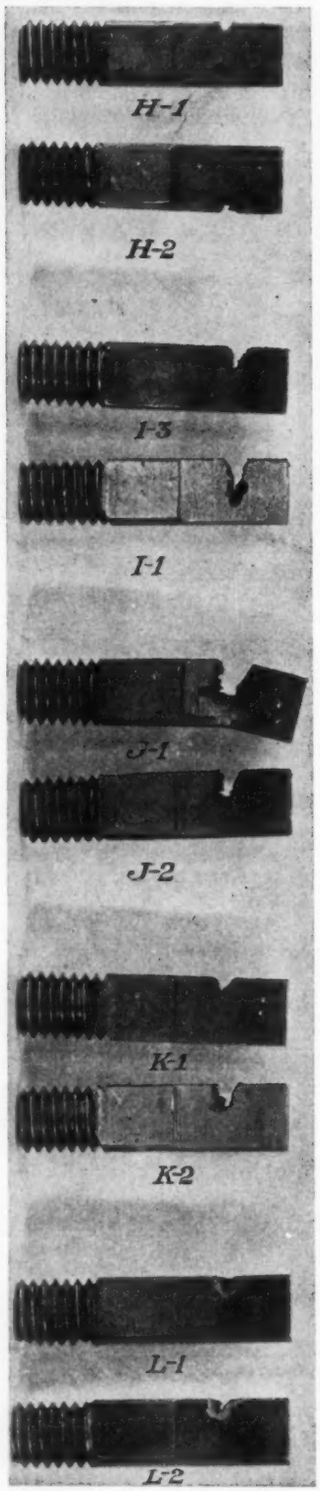


FIG. 11 SPECIMENS FROM EROSION-TESTING MACHINE

Fig. 9 shows the transformer governing system applied to a back-pressure turbine, arranged as a superposition unit to an old station. This diagram illustrates also the conditions for a dual fluid system.

The success or failure of the control system is, to a marked degree, tied up with the detail designs of valves and their operating mechanisms.

In the operating mechanisms, it is essentially a problem of eliminating parasitic reactions, whether originating from friction or from dynamic reactions due to oil flow. For large units, it is often necessary to have one piston for each valve; for smaller machines, an entire group of valves may be operated from a single piston.

The detail design of the valves has proved to be a matter of extreme importance, particularly for the higher temperatures and pressures. The balanced type of valve has generally been used in the past, often as a matter of necessity because of the weak operating mechanisms. Lately, there has been a tendency toward

TABLE 1 EROSION SPECIMENS

(Tip speed, 1000 fps)

Specimen	Material	Approx. hardness, Vickers Brinell	Length of test, min	Loss of weight, per cent	Loss per min, per cent	Comparative erosion resist.
H1 and H2	12% Cr steel with stellite shield	600	30	0.9	0.030	6.3
I1 and I3	12% Cr steel	225	20	3.8	0.190	1.00
J1 and J2	Tantalum	150	8	2.7	0.337	0.56
K1 and K2	5% Ni steel	172	4	1.7	0.425	0.45
L1 and L2	Nitralloy	(?) 200–900	11	1	0.091	2.10

the use of unbalanced single-seated valves of the "plug" type.

The question of materials is a very important one in this connection. At the present time, the preferred combination for high temperatures (above 700 F) is as follows: Stainless-steel valve stem used in connection with nitrided-steel bushings; stainless steel for the female part of the valve seat; valve body of steel with stellite seat, deposited by welding.

EROSION AND CORROSION

The problem of erosion of low-pressure blading is of particular importance, not only with regard to the influence upon efficiency, but also on account of the expense involved in blade repairs. This problem has been given extensive study during recent years, with gratifying results. It is now generally realized that satisfactory results for the high blade speeds can be obtained only by protecting the back of the inlet edge with shields having a hardness in excess of 500 Brinell. Stellite has been found to be one of the best materials for this purpose. By these measures, low-pressure blading can now be operated at tip speeds in excess of 1200 fps with intensities of erosion no worse than formerly obtained with conventional blade steels at 900 fps.

Laboratory investigations have played an important rôle in this connection. Experiments with different materials on actual turbines gave results too slowly and these results were too indefinite. It was not until erosion testing was developed that fully reliable results were obtained, which have since been verified in actual practice. Fig. 10 shows an erosion tester, Fig. 11 a set of specimens, and Table 1 gives typical results. Figs. 12 and 13 show comparison of blade erosion under similar circumstances of the behavior of 12 per cent chromium stainless-steel and stellite shields.

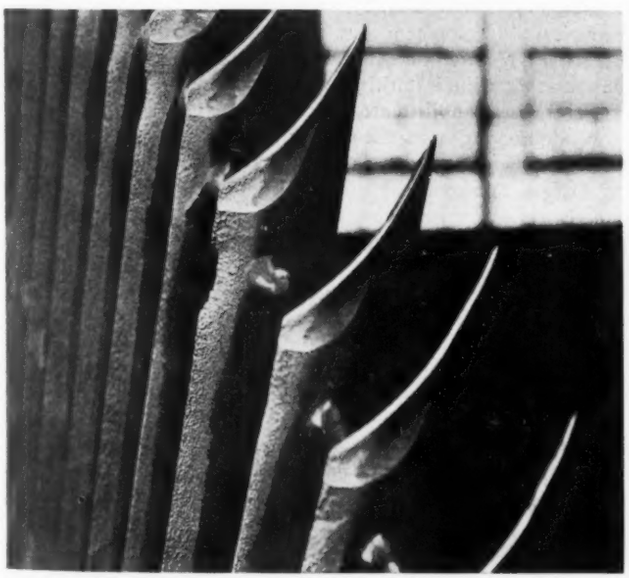


FIG. 12 BLADE EROSION—12 PER CENT CHROMIUM STAINLESS-STEEL SHIELD

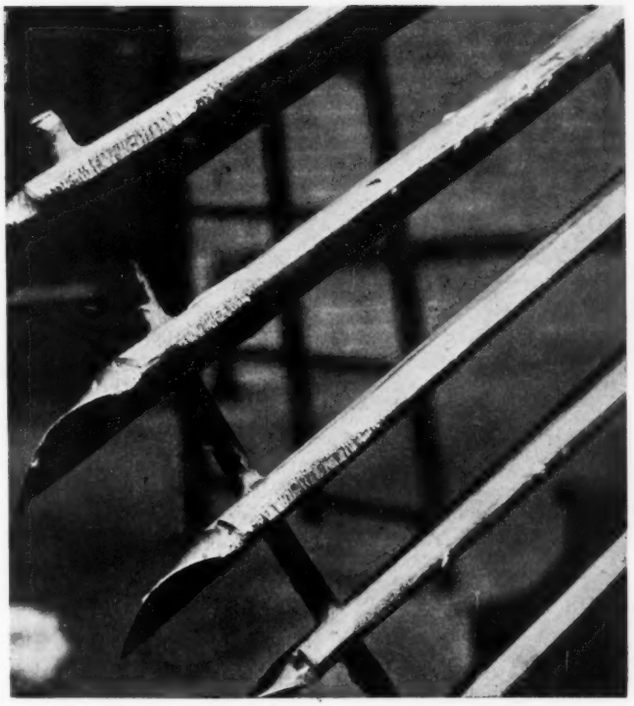


FIG. 13 BLADE EROSION—STELLITE SHIELD

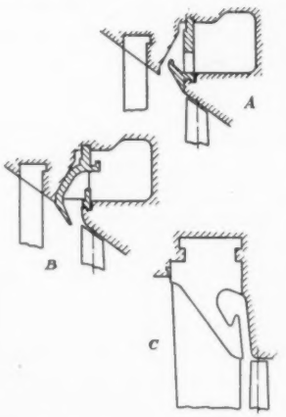


FIG. 14 WATER CATCHERS

Moisture drainage from the last stages of a turbine has been found to be one of the most effective means of reducing erosion. Fig. 14 shows the principal arrangements which have been tried for this detail. Arrangement *A* was tried on a few turbines but the amount of water drained fell short of the expected. With the arrangement shown in *B* experiments have shown that a maximum of 25 per cent of the moisture in the stage may be extracted. The arrangement *C* is a modification of the previous one to accommodate the latest type of construction of stationary blading.

SCALING OF TURBINES

Another problem which is gradually assuming a degree of importance, comparable to the erosion problem is the scaling of blading on turbines operating at high pressures. This problem has come to the front in cases of difficult feedwater conditions, but the indications are that it will become an unavoidable part of operation with high steam pressures.

The exact mechanism of turbine scaling is by no means fully understood, but our present conception of the process is somewhat as follows: In the evaporation process of the boiler, a

FIG. 15 BLADE WITH ARC-WELDED STREAMLINED LASHING WIRES

certain amount of water is carried along with the steam. This water carries with it a certain amount of salts, depending upon the concentration in the boiler. After passing through the superheater, some of these salts take the property of dry dust and would undoubtedly blow through the turbine if they remained in this form. At certain temperatures, some of the salt components in the steam become *sticky* and attach themselves to the blading. The process is cumulative and will continue, if unchecked, until the blade path is almost completely filled up. There are cases on record where a 15,000-kw back-pressure turbine lost 1500 kw of maximum capacity per week due to this cause.

The foregoing theory of stickiness is supported by the fact that scaling always takes place over a certain definite region of temperature, which extends roughly between 400 and 600 F.

It is evident that the most fundamental measures which can be taken to solve this problem apply to the evaporation process of the boiler. The scaling problem has been found particularly serious in installations where the condensate is not returned so that the concentration in the boilers has to be fairly high. In such cases, the feedwater treatment becomes a real problem, and there are limits beyond which the purity cannot be carried. This applies to back-pressure and bleeder turbines for industrial applications. It is probable that such cases are best affected by the use of heat exchangers (evaporators) on the exhaust side.

Up to the present time, it has not been found universally practicable to eliminate scaling by improvement of the evaporation process. It is still necessary, therefore, to find satisfactory methods for removing scales in steam turbines. The first requisite is so to treat the feedwater that the scales are soluble in water. This is obtained by ordinary water-treatment methods. Non-soluble deposits on turbine blading may lead to untold difficulties. The soluble salts are removed by a washing process which is now becoming fairly well established. The temperature of the steam is lowered gradually by injecting water into the steam pipe at a considerable distance ahead of the turbine. It is evident that great care must be exercised in carrying out this process, particularly on high-temperature installations. The water must be entered through specially designed nozzles in finely diffused form and careful records must be kept of temperatures. The washing process undoubtedly represents a severe strain on the turbine, but experience has shown the method to be feasible, conducted in the right manner.

One particularly difficult aspect of the turbine-scaling problem is the corrosion of the blading and other parts, which is inevitable if a heavily scaled turbine is idle a considerable part of the time. A satisfactory solution of this problem is to circulate heated air through the turbine during the standstill so as to keep the deposits dry. The otherwise excellent 12 per cent chromium type of stainless steel is not impervious to the effects of ordinary salt (NaCl) which is invariably present in these deposits. This fact should be remembered in the choice of blade material for installations in this class.

BLADE FAILURES

No item has figured more heavily in the maintenance of steam turbines than the blading. An important part of this is directly attributable to corrosion and erosion; there are many cases of mechanical failures of sound blades, however. It is becoming recognized that these failures can generally be attributed to vibrations and that they depend only indirectly upon the steady loadings due to steam or centrifugal forces. Marked progress has been made in this respect by recent laboratory methods in detecting weaknesses of design and materials of turbine blading. An electromagnetic vibration tester has been designed in which structures can be tested to destruction under frequencies as high as 20,000 cycles per second.

Blade failures are of particular importance if they occur in the last rows on large condensing turbines. The blades of these rows are very long and slender and, as such, subjected to many forms of vibrations. It has been customary for a long time to stiffen these blades by circular lashing wires silver-soldered to the blades. On very large blades, these circular wires became heavy in section and the silver soldering was found to be an unreliable form of mechanical fastening for variable stress. As a result of this experience, some time ago the method was introduced of using streamlined lashing wires arc-welded to the blades, as shown by Fig. 15. This method has required a long process of development but it has been found satisfactory. Moreover, research on this problem has given methods for predetermining failures in this type of structure and has brought us much closer to an ultimate solution of the problem.

We do not yet know the exact mechanism of blade failures in the low-pressure end other than that they are invariably caused by fatigue due to blade vibrations. Whether the vibrations are always of the resonance type, or whether they also may be of the self-excited (steam flutter) type is not yet fully established. In a few instances the failures can be traced to obstructions of the exhaust near the last rotating row. In such cases, the blades are almost certain to fail if the natural frequency of the blade groups coincides with the frequency of the impulses caused by these obstructions. The damping of the blading is bound to be of fundamental significance in such instances.

In many cases it is impossible to classify the vibrations in this manner, however. In some cases there is no possible clue to a specific disturbance and in others the natural frequencies can be proved to fail outside of the conditions of resonance. The cause of failure must then be attributed either to self-excited vibrations due to the action of the steam, or to ordinary forced vibrations. The natural frequency cannot be of particular importance in such cases. Damping will play a significant

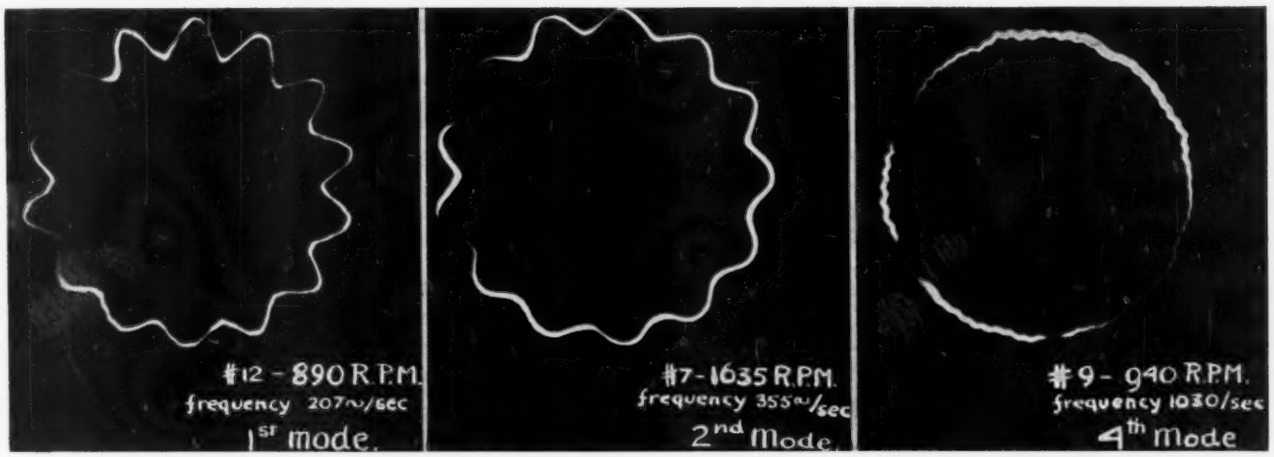


FIG. 17 TYPICAL RECORDS FROM BLADE-VIBRATION TESTING MACHINE

rôle in the former case, but will be unimportant in the latter.

At the present time, we are forced to proceed without exact knowledge with regard to these questions. The only solution available is to make sure that all possible obstructions of the exhaust are removed and that the natural frequencies of the blade groups are such as to exclude any possibility of resonance with those obstructions (such as the horizontal joint) that cannot be completely eliminated. It also appears important to make the inherent damping of the blade construction as effective as possible and to arrange the structure so that the initial failures always take place in the lashing wires.

Outside of the special considerations surrounding these measures, there remains the all important requirement of making the blade construction as immune as possible to vibratory stress. Laboratory tests are valuable in this connection, and the new electrodynamic tester has proved to be an extremely useful tool.

It is no simple matter, however, to devise a conclusive method of interpretation of test results obtained by this method. In which mode of vibration should the structure be vibrated and how can two structures with different frequencies be compared?

So far, the laboratory tests have consisted in vibrating a blade group at its lowest mode of vibration until a failure is obtained. The intensity of loading has been defined, rather arbitrarily, as the total maximum inertia force, integrated along the length of the blade. For blades of similar shapes, this is proportional to the product of the amplitude of vibration at the tip of the blade and the square of the frequency.

The first failure will occur after a greater or smaller number of reversals, depending upon the choice of the amplitude. It is evident that a structure which fails after a small number of reversals has had the benefit of a greater fatigue strength but was tested at a needlessly high amplitude. To correct for this influence, a typical fatigue curve representing the average in shape of a large number of fatigue curves of blades and lashing wires of different materials and treatment has been developed. By dividing the intensity of loading as defined in the preceding paragraph by the relative fatigue strength given by the curve, a comparative value of the strength of the structure is obtained.

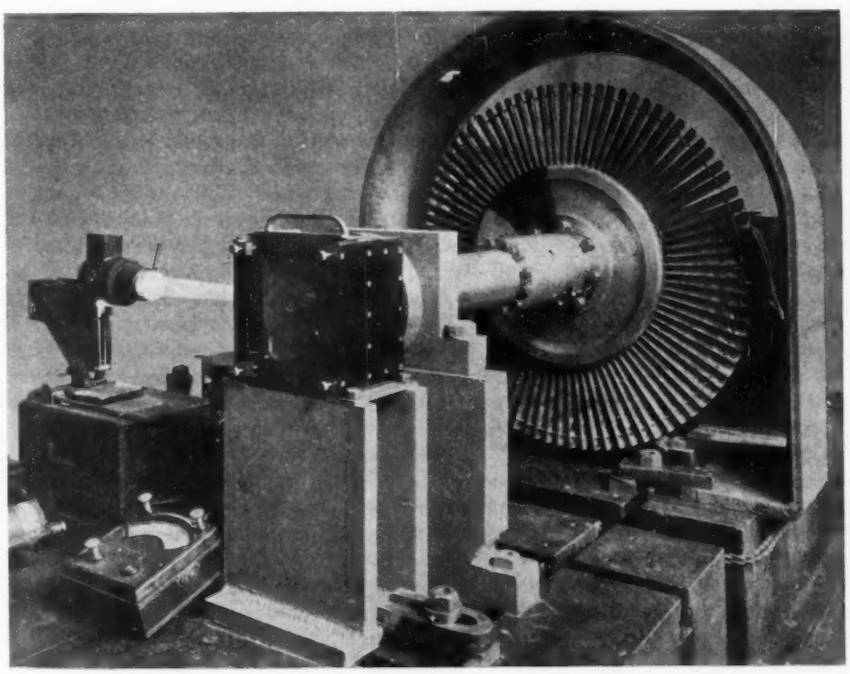


FIG. 16 MACHINE FOR TESTING BLADE VIBRATION

A measure of the damping is obtained by recording the input required to maintain the amplitude of vibration of the model. Beyond a preference for the greater damping, we cannot yet evaluate the significance of different degrees of damping. Moreover, it is difficult to control the damping at will; large damping usually being synonymous with low fatigue strength. The best form of artificial damping known to us so far is that introduced through the erosion shields.

Valuable information on the subject of damping has been obtained by exploring the blade vibrations during rotation. Fig. 16 shows an arrangement for this purpose in which this has been accomplished. Fig. 17 shows an example of the type of results obtained.

The Commercial Aspect of ENGINEERING

Second of a Series of Addresses Being Delivered at the Engineers Club of Baltimore

By WILLIAM McCLELLAN

POTOMAC ELECTRIC POWER CO., WASHINGTON, D. C.

THE subject tonight is one that I am going to discuss from the standpoint of the younger engineer. I am going to talk of the growth of business experience of engineers.

It seems to me that first we have to understand what business is—not necessarily make a definition that would go into Webster's or Funk and Wagnalls', but for the purposes of this talk. The term "business" is used in a generic sense. We talk of people being in this business or that business—the law business, the engineering business, the steel business, the cement business, the electric business, and whatnot. We mean, generally speaking, anything that one is busy about. But that doesn't help much because nobody is busier than engineers. It must mean something else.

For the purpose of this talk tonight let us think of business as an activity in which some one takes money, in one way or another, and puts it out with the possibility of making or losing on the use of that money. A man is in business if he buys twenty rolls of silk and puts them on a shelf, hoping that he can sell them at a profit; but he runs the risk of losing or making. That's business. A man who decides to put up a factory and make something in it, hopeful, but not knowing whether he will make or lose, is risking money, and is in business. In the electric business it is decided to develop a certain system requiring the investment of $100,000. It may or may not be successful, but the element of judgment comes in. That is business. Such activities are different from law or other professional activities. I have never thought that a surgeon, no matter how great he is, was in business. He is a professional, he is running other risks, but not money risks. A lawyer or a doctor can equip too elaborately, spend too much, but when he starts "to do business" he is risking his time and reputation, but not money. We are talking of risking money.

Then again we have to define what we mean by "engineer." An engineer in the old days was a man who designed and constructed, or did both. That is a rough and ready definition. Loosely, today, we use the term in a variety of ways. A man may graduate from engineering school and we may call him an engineer. He is not an engineer because the college does not recognize him as one and will not give him a degree as such. The college makes him go out and earn the engineering degree. In one, or two, or three years it may give him a degree as an engineer. A man really comes out of college as an engineer graduate. If he happens to go into a sales organization after he leaves college, it seems to me it is a grave question as to just what he is. He is an engineering graduate, but he is going into selling, which is business primarily. It is professional in the sense he is not risking money. He is practicing business methods, however, as an agent. It is a grave question as to whether he has ever practiced engineering at all. If he is a first-class salesman and concentrates his mind and energy on selling, he will find to a certain extent that engineering is quite a handicap. Instead of such a talk as this, he might profit from one on "The Engineering Contacts of a Business Man." However, when I talk of an engineer today, I am thinking of the average graduate who has left college and has a job. He may be a foreman of a lot of laborers putting in the foundation of a turbine, or he may be at a drafting board or in the testing room. In other words, at engineering work as we understand it in this restricted sense.

BUSINESS EXPERIENCES DO NOT USUALLY DEVELOP EARLY IN THE ENGINEER'S CAREER

The first thing to be noted is that business experience comes later—it does not start immediately. This is very important. In everything you do, when you are a young engineer on your first job, the technical features are the things that impress you. You have little opportunity to understand the business relationships of what you are doing, although they may be many. Some superior is attending to that. Some superior tells you what to do, and it is a technical assignment. He is probably thinking very much of the business features of what he is asking you to do. You concentrate on the technical task which is placed before you. You are intensely interested in the technical features—they usually absorb all your attention. If you get any knowledge whatever of the business relationships and contacts that enter into that particular task, they seem very much involved and quite complex.

Inasmuch as later on you will discover for yourself that the business features of any engineering job are extraordinarily essential, and demand the most elaborate attention, it is important that you, as a young engineer, get a glimpse of them as early as possible. Sooner or later, as you grow in experience, they will arise. If you have not thought about them and have not understood them, you will not be ready to meet them, even as a tyro.

EARLY PREPARATION FOR BUSINESS EXPERIENCES IS NECESSARY FOR THE YOUNG ENGINEER

You must prepare yourself for the inevitable business features of the work when they do arise. Your first business experience may surprise you. Let us say you are asked to design an oil house or put up some kind of a pole line. You will go to work on it and, with all your technical ability, do a fine job. You may find that the boss turns it down. You know that it is a good design and, if they want to build a pole line or an oil house, they can't do better than take your design. Yet they

turn it down; it won't do. You suspect that the boss is not half the engineer you are.

I have known many engineers—some prominent ones—that could never get over that particular point of view. Their solution was not the right one, although from the engineering standpoint it was a perfectly good design.

What is the trouble? The probability is that the explanation of the difficulty will be found in the failure to consider one or all of four business features; first, the capital cost; second, the annual cost; third, the time element; and fourth, the local suitability. These are in reality not separate features, but are all interrelated. Each one impinges on the others to a greater or lesser extent.

CAPITAL COST AFFECTS ENGINEERING DESIGN

The capital cost is simply what is going to be spent to complete the project and get it ready for operation. Perhaps the owner has not the money and cannot get it. It may be that it would be more profitable to him if he could adopt the design offered, but he is estopped because he cannot possibly pay for it, and, having to go ahead on some basis, must demand a less expensive design, irrespective of other features. Some of the most successful projects have been started with limited capital and required adaptation of design for this reason. It is not the business of the engineer, of course, to surmount this difficulty, even though he knows such limited capital may impose penalties in the way of operation.

On the other hand, it may be that the owner has the capital, but is of the opinion that he ought not to spend so much for one particular feature. In this case there is more room for the engineer to argue, provided he fully understands the business relationships, as to the advisability of a change of opinion on the part of the owner. It is equally his task, with a proper appreciation of business relationships, to help the owner meet the difficulty if it it is a real one. The important point is to see that in the final design adopted there is no waste of capital cost, and that whatever is done is, as far as possible, made a part of a design which can be completed later when, perhaps, more capital will be available without avoidable loss of anything that has been spent.

ANNUAL COST MUST BE CONSIDERED

Perhaps the engineer has not given sufficient attention to the annual cost of his design. This annual cost is made up of a number of factors, the principal ones being the interest on investment, the annual depreciation cost, the insurance cost, the taxes, the cost of operation, and the cost of maintenance. The engineer must remember first of all that the owner must pay all of this annual cost presumably out of earnings on the design which he is to furnish. The design may be perfect in every way, but the owner simply cannot afford to pay the annual cost. Other things being equal, this is the really controlling factor in connection with the design, assuming that the owner could construct it and pay for it. He is in business to make money, and, irrespective of the fact that perhaps he ought to do what the engineer is suggesting, he is not in a position to do it. Do not forget also that he may have to get into a reasonable earning position in order to build up the credit of his venture so that he can get more money as it is needed.

It is not to be overlooked, however, that an engineer with proper understanding of business might convince the owner to accept a narrow earning position for a year or two if this particular construction would put him in a much stronger position later and, in fact, enable him to make greater earnings. As in the former case, it is important to the engineer, if he is compelled to change the design for these reasons, to make sure that he changes it in such a way that additions can be made to the design at a later date, if possible, to bring the project to its best position.

THE TIME ELEMENT IS IMPORTANT

This brings us to the question of the time element. Every structure or machine has an accepted life period. It may be profitable only if it can be used for this whole life period. It may be unprofitable if this life period is cut short and the unused life cannot in any way be compensated for. Certain circumstances may control this. For example, a railroad for a logging operation may be good for twenty years; but if the logging operation cannot possibly last for more than three years, such a condition ought to be very carefully considered in the design. Again, if certain parts of the design will wear out in three years, some consideration has to be given to whether such parts are easily replaceable as maintenance or whether the whole machine has to be discarded and a new one installed.

LOCATION MAY BE A DECIDING FACTOR

Finally, we come to local suitability which has some relation to the time element. For example, even though the equipment were more or less the same, the same design of substation would not be used at a coal mine as would be used for the principal corner of a large city. Noise, smoke, and dust may be serious factors in one place and not in another. In a power house, for example, there may be some very old and perhaps inefficient units still in operation. As an engineer, you may wonder why these units have been kept and why modern units are not installed. With business experience, however, and the knowledge that the units were perhaps used for an hour a day and a few days in the year to generate the kilowatt hours of an occasional peak, it would be realized that they were locally suitable, whereas, under other circumstances, they would be quite out of place. Hence a design may be unacceptable for the reason that it lacks certain intangible features which have a business value to the owner. There may be advertising value involved or a substantial and prosperous appearance may have value. All these features must be considered apart from the mere technical excellence, or what we call strictly engineering features.

The question of the business relationships of engineering is an exceedingly complex one. It is perhaps best illustrated by the fact that the same owner would reject a design for one set of circumstances and accept it for another set of circumstances. Of course, if the young engineer is working in an organization, the owner or person in charge of ordering the design ought to give some indication of these features in order that the design may not be made entirely in the dark. The point is that the young engineer should, as quickly as possible, learn to have an appreciation of what is involved, even though the decision is not his. Then, as he advances to the position where perhaps he will finally have to make the decisions on such matters, he will be ready to do so. In such a position, the engineer of experience will look at the engineering features and business features together and finally arrive at a proper conception of the problem.

The young engineer down the line, however, should not mix engineering and business. He cannot do so unless he is fully informed as to the business situation. It is really his business as a junior, and lacking complete information, to concentrate more on the engineering features of his work and not make assumptions in regard to business features. When, as head of an engineering organization, I required my junior engineers to do this, I did not want an engineering report, for example, offering suggestions or designs in which engineering features had

been sacrificed with the thought that the young engineer knew what I wanted or what would be advisable for me to have. Of course, if I advised him in advance that I wanted the cheapest plant in first cost that would do the work, it was his business to do it for me. On the other hand, if I told him that I wanted the most economical plant possible, it was his business to do that. In the absence of direct orders of this sort, it seems to me that the engineer, as such, must offer what he would consider the most economical design—everything considered.

MEETING SALESMEN DEVELOPS RESPONSIBILITY

The next business field of experience for an engineer is perhaps in meeting salesmen. This is more strictly a psychological experience. It is simple when the salesman has only one class or quality of apparatus to sell. It is quite different when the salesman has an extended line of different classes and qualities of apparatus, all of which will perform the general service required. After all, the salesman is interested in making sales. He would prefer to sell his highest class and best quality. The honest salesman, if called upon for advice, will tell the peculiar advantages and disadvantages of some particular class, but after all it is the designing engineer who must make the choice, and certainly make the final decision. All salesmen are not good salesmen, even though the individual is intrinsically honest. Business experience will teach an engineer to get all possible information from a salesman and then to make his own decisions.

Sooner or later the engineer will gain business experience in connection with what we call promotions. These promotions may take the form of an independent project for a new venture or through the enthusiasm of some official of a company who wants to introduce a new system of doing things. It is dangerous to mix promotion and engineering. The relationship is somewhat akin to that between the salesman and the engineer. The engineer should not be carried away by the needs of the promoter to making any concessions whatever in his engineering design from the standpoint of effectiveness and cost.

PREPARING CONTRACTS PROVIDES BUSINESS EXPERIENCE

Finally, business experience comes to the engineer in the making of contracts. Sooner or later the engineer will have to join in the making of contracts for the performance of certain duties for the exchange of services, etc. Here, as a rule, he will meet lawyers who will word the contracts, their real function being to state accurately the idea and relationship that is to be carried out. The engineer, however, must think of the business side of the contract if he is to be effective. He may, for example, put something in a contract which is theoretically perfect, but, like the machine he designs, it may be necessary to work it out mentally to see if it is practical or even practicable. Provisions may be put in a contract which will cost far more to carry out than they are worth. Accuracy in all the features of a contract is very desirable, but approximations may be much more useful and may work more smoothly. A contract for the sale of electric power or the moving of material cannot be done as an exercise in a laboratory. Consideration must be given as to who is going to carry out the terms of the contract. Perhaps ordinary people, instead of fully qualified technicians, are involved, and the terms must be made suitable to their abilities.

AN ALERT INQUIRING ATTITUDE HELPS

I have tried to illustrate in a very general way what I mean by the business relation of engineers and if there is such a relationship, you ought to be searching for and trying to understand the full meaning of it. As you go through life and accumulate experience, learn to wonder and think about what you see. If wheelbarrows are being used for moving dirt, you should wonder why a horse and wagon are not used, or perhaps a conveyer. If you see an oilhouse being built—here of rough lumber, elsewhere of brick—you should wonder why such different structures are used for apparently the same purpose. If you go through power houses and see totally different solutions of apparently the same problem, it is wise to wonder whether this is the idiosyncrasy of some engineer or whether there is something fundamental to it.

When I was teaching school, I noticed that some of the boys, given a problem on a piece of paper to work out at the blackboard, would walk up, glance at the problem, and immediately start to solve it. Then I frequently noticed that they rubbed out what they had done and read the problem. There are a number of engineers like this. They start with their theoretical knowledge to design something, they get part way through, and then they have to scrap it because, in many cases, they have never sensed the problem. A well-known proverb is: "A problem well stated is half solved." I ask you to remember that the technical features of any engineering problem are only part of the problem inasmuch as everything you design costs money to construct and money to operate. You will be finally successful only to the extent to which you give adequate consideration to both these features.

The Equation of State for Superheated Steam

(Continued from page 164)

$$\left(\frac{\partial H}{\partial p}\right)_T = \left(\frac{\partial v_T}{\partial \tau}\right)_p = \left(\frac{\partial B_T}{\partial \tau}\right)_p \quad \ldots\ldots\ldots\ldots [4]$$

It is evident therefore that the measurement of $(\partial H/\partial p)_T$ is equivalent to a direct measurement of the equation of state quantity B. To show this we may proceed by representing $\frac{\partial B_T}{\partial \tau}$ by $\psi_0 + \psi_1 p + \psi_2 p^3 - \psi_3 p^{12}$ where ψ_0, ψ_1, ψ_2, and ψ_3 are pure temperature functions. On integrating we have

$$B = T[\int \psi_0 d\tau + p \int \psi_1 d\tau + p^3 \int \psi_2 d\tau - p^{12} \int \psi_3 d\tau] \ldots [5]$$

The ratio of $(\partial H/\partial p)_T$ and dT/dp gives the heat capacity in accordance with the thermodynamic equation

$$C_p = -\frac{(\partial H/\partial p)_T}{dT/dp}$$

THE HEAT CAPACITY OF SUPERHEATED STEAM

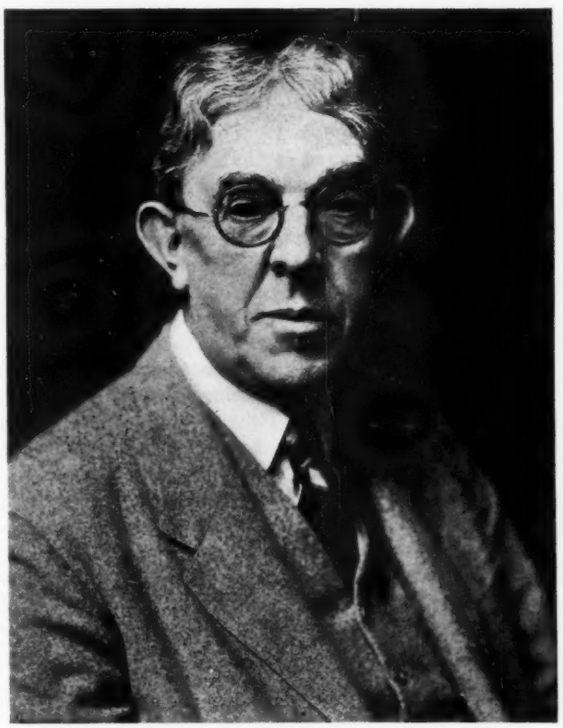
Last year a diagram was given wherein computed values of C_p at constant pressure were entered as ordinates with temperatures as abscissas. It was discovered during the year that an error of computation in the p^{12}-term of the equation of state had lowered the computed values slightly as the saturation line was approached. The general aspect of the diagram remains unchanged and Koch's latent-heat capacities are in excellent accord with the computed values. The older values of Knoblauch and Koch appear large relative to the computed values. It is believed that the accord between the heat capacity computed and the new observed data of Koch is very satisfactory.

The new calorimeter for measuring $(\partial H/\partial p)_T$ and dT/dp has been considerably improved during the year, and the hope is entertained that much more precise data will be secured for the range 60 to 150 C and to pressures approaching saturation.

PALMER CHAMBERLAINE RICKETTS
1856–1934

PALMER CHAMBERLAINE RICKETTS, President and Director of the Rensselaer Polytechnic Institute, which he had served as instructor to president during sixty successive years, and honorary member of The American Society of Mechanical Engineers, died at the Johns Hopkins Hospital, Baltimore, Md., on December 10, 1934.

From an institution of less than two hundred students he had seen Rensselaer grow to seventeen hundred students and from two buildings to twenty or more. For most of this growth he was largely responsible, owing to his scholarship, foresight, and administrative ability. Of the present buildings used by the Institute, only three were erected before his presidency. At present there are twelve distinct courses offered by the Institute, of which only one was offered at the time he undertook the direction of the Institute. This expansion has been the result of his conception of the field of endeavor of a true polytechnic institute.



PALMER CHAMBERLAINE RICKETTS

Palmer Ricketts, the son of Palmer C. and Eliza (Getty) Ricketts, was born at Elkton, Cecil County, Maryland, on January 17, 1856. His early boyhood was spent in Maryland, but in 1865 after the death of his father the family moved to Princeton, N. J., and here he was prepared for college by Mr. John Howard O'Brien, a tutor in Latin of Princeton College, and entered the Rensselaer Polytechnic Institute in September, 1871, at the early age of fifteen.

His high scholastic record was remarkable and was gained while he participated in the student activities of that day. In 1875, at the age of nineteen he received his degree of Civil Engineer with twenty-three other young men.

In 1874, during the student days of Palmer Ricketts, the Institute celebrated the Fiftieth Anniversary of its founding and from the student body of less than 200 members, eleven men received the degree of Civil Engineer in that year. The C.E. degree was the only degree conferred by the Institute at that time.

On account of his high scholarship Palmer Ricketts was offered an instructorship in mathematics and astronomy, which so appealed to him that he accepted this rather than entering at once into the practice of engineering in the activities of that day, although he carried on practical work in connection with his teaching, as assistant engineer of the Troy and Boston Railroad in 1876.

In 1882 he was made an assistant professor of mathematics and astronomy, and in 1884 he was appointed the William Howard Hart Professor of Rational and Technical Mechanics, which had previously been held by the late William H. Burr. The success of his teaching in structures and hydraulics was so outstanding that he became a consultant in bridge engineering of the Rome, Watertown, and Ogdensburg Railroad in 1887, the engineer of the Public Improvement Commission of Troy in 1891, the River Commission of Corning in 1897, and the designer and supervisor of erection of a number of bridges and hydraulic structures.

His work at the Institute prepared him as an expert in patent causes and he presented testimony in important litigations between the years 1886 to 1897.

In 1892, after the resignation of Director D. M. Green, Palmer Ricketts, at the age of thirty-six, became the director of the Institute under the presidency of John Hudson Peck, a lawyer of the City of Troy, N. Y. The separation of the directorship from the presidency caused much difficulty in the management and development of the Institute, owing to the lack of understanding of the educational needs of the Institute by the presiding officer of the Board, so that the early days of Director Ricketts were filled with trips from the "Hill" to the city with requests and arguments. Fortunately, in 1901 the two offices were combined and Director Ricketts became president and director. Although president for the last thirty years he was always affectionately called "the Director," a title which his loyal friends used, and, we believe, he liked.

On November 12, 1902, Director Ricketts married Miss Vjera Conine Renshaw, of Baltimore, Md., and this wedding was marked by demonstrations of affection and admiration for the Director by the faculty and student body. This affection and admiration for him has been extended by the faculty and students to his wife, who entered into and shared all of his plans and activities during the full term of his presidency.

In 1904 the burning of the main building was the beginning of a new Institute, the monument to the ability, wisdom, and perseverance of Director Ricketts. Such a catastrophe as the fire is often a blessing in disguise. It proved so in this case. With the major part of the plant destroyed, an offer was made to transfer the Institute to a large university with the retention of the name of the Rensselaer Polytechnic Institute, but President Ricketts with his faculty determined to remain at Troy and build again on the foundations established three-quarters of a century before.

After a conference with the late Capt. Robert W. Hunt, Director Ricketts went to Andrew Carnegie and persuaded him to give $125,000 for a new building. Then money was raised to purchase the Warren House and grounds on Eighth Street and money was given by Mr. J. J. Albright for part of the cost of the William Weightman Walker Laboratory, named in memory of a graduate of the class of 1886.

Director Ricketts then persuaded Mrs. Russell Sage to give a sum of one million dollars to found a course in mechanical engineering as a memorial to her husband. This was in the year 1907 and at this time the Institute, under the guidance of the Director, inaugurated the courses in mechanical engineering and electrical engineering.

From here on the years have brought to the Institute gifts for buildings and endowment from alumni, friends, and citizens of Troy and an enlargement of its field of education. A recital of this progress would show the regard and trust which these donors have had in the man who indicated the needs of the institution which he had loved, served, and directed for more than a generation.

Following the introduction of courses in mechanical and in electrical engineering, the course in chemical engineering, and, subsequent to 1922, courses, in arts, science, and business administration, in physics, in chemistry, in biology, in architecture, in metallurgical engineering, in industrial engineering, and in aeronautical engineering have been added.

In all of this development Director Ricketts was guided by the thought of service. His theory of admissions and his desire to increase the work offered by the Institute was inspired by his desire to give to those who wanted an education in some field of technology a chance to prove their worth. He always thought that offering a chance to those who might make good was more important than the insistence upon formal admission examinations.

In the administration of the Institute, he was ever the champion of those who did not receive the "fair deal." Although believing in student activities and student life, he was not willing to have hazing or freshman rules interfere with the free life of every member of the student body. His stand against hazing came only when this form of student life went beyond bounds of decency, fair play, and even morality. He was ever willing to remain firm to his convictions, even under adverse criticism from students or alumni. His ability to handle student discipline was remarkable and effective. In its administration he had his fixed conviction, but his great sense of humor was a wonderful aid in this work.

He was interested in the possibility of aid, financial and scholastic, for the students needing such. To him personally many owe their graduation, for without his aid it would have been impossible to continue.

Director Ricketts stood for the highest scholarship from students and faculty, and never did he deviate from the motto of the Institute, "Knowledge and Thoroughness," in his administration of Institute educational policies. He insisted on the traditions of daily recitations, and topic work and even in the "scholastic amusements," as Amos Eaton called the work in the laboratories, the work had to be tested by the final examination.

AMOS EATON HALL AT RENSSELAER (LIBRARY AND AUDITORIUM)

In 1924 the Institute celebrated the Centennial of its founding and Director Ricketts was most happy in the recognition which came to the Institute from governments, prominent engineers, and educational institutions of the whole world through the greetings of those in attendance at these extensive ceremonies.

Director Ricketts was active in civic affairs as shown by the positions held at the time of his death. He was a trustee and vice-president of the Troy Public Library, a trustee of Dudley Observatory of Albany, N. Y., of the Albany Academy, of the Albany Medical College, and the New York State College for Teachers. He was a director of the Samaritan Hospital of Troy and vice-president of the Rensselaer County Tuberculosis and Public Health Association. He was also a Director of the National City Bank of Troy.

In 1905 Stevens Institute of Technology conferred upon Director Ricketts the degree of Doctor of Engineering and in 1911 New York University conferred the degree of Doctor of Laws.

Director Ricketts was a member of the American Society of Civil Engineers for many years and a vice-president in 1916. His connection with The American Society of Mechanical Engineers extended over forty-four years, and in 1932 he was elected to Honorary Membership. Following this election by our Society he was also elected an honorary member of the American Society of Civil Engineers. He was a commander of the Order of the Crown of Italy and a Commander of the Legion of Honor (France). He was a fellow of the American Association for the Advancement of Science and a member of the American Philosophical Society. He was also a member of the American Institute of Mining and Metallurgical Engineers, the Institution of Civil Engineers of Great Britain, and Sigma Xi.

Director Ricketts has written two histories of the Rensselaer Polytechnic Institute and a number of papers have been contributed by him to the State Commissions on Railroads and on Education, to the technical and daily press, and to the Proceedings of technical societies. In all of these he was a clear and forceful writer, free from all sham and uncertain expressions.

Not only was Director Ricketts a man of great foresight, administrative ability, and perseverance but he was a most helpful leader under whom to work. He would listen carefully to your plans and suggestions and then give you the authority to carry out plans which he approved. He never withheld praise for good work and in many cases where adverse criticism might have been offered by others he would take the responsibility himself and assume any blame attached to the transaction. His faculty and his trustees were always ready to follow his lead after a decision had been reached by discussion. His force of character, his human interests, and his devotion to Rensselaer remain as a cherished memory and guiding influence for our work in the future.

As was written of Wren in St. Paul's so of Ricketts at Rensselaer we may write in clear letters: "If you ask for my monument look about you."—ARTHUR M. GREENE, JR.

ENGINEERING PROGRESS

A Review of Attainment in Mechanical Engineering and Related Fields

AERONAUTICS

Pemberton Billing Durotofin

THIS machine combines some of the parts of the autogiro and some of the parts of the paddle wheel. It uses centrifugal loading as in the autogiro to help in getting over the worst structural difficulties of the paddle wheel. The propulsion system of the paddle wheel is turned up on end vertically and provides struts for the blades and rotors. The machine has a normal airplane fuselage and a gear drive to the rotors. The latter are driven positively at the same speed but in opposite directions to balance the gyroscopic force and couples. A free-wheeling mechanism in the gear, mounted on the rotor axes, allows for free autorotation of the rotors if the motor cuts out. It is claimed that with this machine vertical climbing and descending flight would be possible as well as the ability to hover. It has been proved conclusively in both model and full-scale tests that the form of rotor employed will autorotate freely because of the wind-milling effect of the passing air flow. The actual machine apparently has not been built. The inventor is the founder of the Supermarine Aviation Works at Southhampton and a man of high standing in the British aeronautical field. (*Aeroplane*, Section Aeronautic Engineering, vol. 47, no. 1227, Nov. 28, 1934, pp. 657–658, 2 figs.)

Air Transport

THE following recommendations of engineering interest have been made by the Federal Aviation Commission, Clark Howell, chairman:

It should be the policy of the United States to maintain a position of world leadership in air transport, and to lend such aid as may be necessary to insure that the most modern and efficient equipment and methods shall be applied on American domestic and foreign air lines.

It should be the general policy to preserve competition in the interest of improved service and technological development, while avoiding uneconomical paralleling of routes or duplication of facilities.

The control, in the interest of public safety, of the minimum standards of equipment and the operating methods and organizations and ground facilities of civil aeronautics should continue approximately as at present, but under the jurisdiction of the commission (proposed elsewhere in the report).

There should be no attempt to require the inclusion of military features in the design or equipment of transport airplanes.

It should be the policy of the government to impose a minimum of regulation upon private flying, and to determine that minimum with reference to public safety alone. The technical regulations of aircraft and personnel engaged in commercial activities should remain substantially as at present.

The National Advisory Committee for Aeronautics should give the development of those qualities in aircraft which render them particularly suitable for private operation an enlarged place on its program of research, and should cooperate with the Department of Commerce in determining the qualities and performance of aircraft of new types which may be offered for consideration.

The usefulness of gliding and soaring flights in the promotion of aeronautics, and in the aeronautical activities of the various departments of government, should be carefully studied. In particular, the authorities charged with the technical regulation of aircraft should give special consideration to glider problems and to means of simplifying the formalities connected with glider control and licensing.

The paramount importance of quality in military aircraft should be recognized, and procurement policies should be fixed with primary reference to the securing at all times of the best material. Price should not be the primary consideration.

The Army and Navy should adopt a policy of holding design competitions by which details of the military characteristics of the aircraft and equipment desired to be created shall be disclosed only to fully responsible competitors of American nationality, and qualified for the work contemplated in the opinion of the Secretary of War or of the Navy.

It should be the policy of the United States to undertake further construction and operation of rigid airships in naval and commercial service.

The Navy should determine by actual experience the scouting value of airships, and the need for their further construction for naval purposes.

The degree of control by the government of the design and construction of civil aircraft should remain for the time being approximately as at present. The ultimate purpose should be a minimizing, in the degree consistent with public safety, of detailed control over the work of responsible manufacturers maintaining an adequate inspection and engineering organization of their own.

The examination of a new type of aircraft by the government should include a numerical determination of all the essential elements of performance, and the figures so obtained should be recorded in the approved type certificate.

The principle of cross-licensing of patents in the aircraft industry should be recognized as beneficial to the government and as promoting a rapid development, and should be encouraged. The government should take an active interest in the operations of a cross-license association, membership in which is open to all on reasonable terms, to insure fair treatment for all participants in its affairs and to protect the government's interest. The commission (proposed elsewhere in the report) should be authorized to act as an adjudicator, either between private parties or between a private party and a government department, in such cases arising under such an agreement as the commission may elect to hear.

The National Advisory Committee for Aeronautics should remain the central agency of governmental research in aeronautics, and also the recognized body for coordinating experimental and developmental work of the various government departments and the results obtained from the researches of various institutions. It should extend its mechanism of unpaid subcommittees to include frequent conferences upon particular questions with technically qualified representatives of the commercial industry, and to draw the industry's personnel engaged in the development of aero-

nautical products more directly into the planning of its research work.

The best qualities of present-day aircraft are preeminently due to organized research work, and the work done by the government in that field has paid for itself repeatedly in the improved service that aircraft have been able to render as a result. The extent of such governmental research work should be increased to substantially above its present level as rapidly as the personnel can be trained and special laboratories equipped.

The National Advisory Committee for Aeronautics should have a moderate appropriation specifically earmarked for the support of approved research projects at universities and other semi-public institutions which have a competent staff and proper equipment to perform the work, and should be authorized to contract for the conduct of such researches and to publish the results. (Report of the Federal Aviation Commission, January, 1935, printed by the United States Government Printing Office, 1935, 254 pp.)

AIR ENGINEERING

Air-Receiver Explosions

THERE seems to be no doubt whatsoever that it is the oil used for lubrication that forms the basis for an explosive gas or vapor in air receivers. However, the rate at which oil is ordinarily fed, even with excessive lubrication, would seem to be such as to form so weak a mixture of oily vapor and air that it would not ignite. Moreover, oils do not flash or take fire spontaneously in the atmosphere by merely raising them to their flash or fire-point temperatures. They must be ignited by a flame. The ignition temperature of an oil or gas is quite different from the flash or fire point. It varies for different oils or greases, but in general it is in the vicinity of 1000 F at atmospheric pressure, which is considerably higher than the temperature that could theoretically be obtained at ordinary compression ratios even by the poorest type of compressor. Viewed from these considerations it would appear to be impossible to obtain a temperature high enough to ignite the oil-vapor mixtures, yet explosions do occur so, obviously, ignition must take place. The author does not consider discharges of static electricity as a likely source of ignition.

Tests were carried out at the University of California a few years ago to determine the effect of a leaky discharge valve and it was found that while the temperature of the discharge air at the end of the cylinder with good valves reached a value of approximately 235 F, with a leaky valve the temperature rose to 320 F. At the same place an investigation was made of the effect of throttling the intake air and it was found that this throttling increased the ratio of compression-discharge temperature. The National Advisory Committee for Aeronautics (Technical Memorandum 299) reports an investigation conducted in 1924 by two Germans, Tausz and Schulte. They showed that the ignition temperature of gasoline and air mixtures is decreased by increase of pressure. For instance, a mixture of gasoline and air, which, under a pressure of 2 atm ignited at 707 F, required a temperature of only 464 F when under a pressure of 8 atm. It was also found that certain oils which have a comparatively low ignition temperature at atmospheric pressure may have a comparatively high ignition temperature when under a higher pressure. With other oils and greases the reverse is true. It would appear therefore that increase in pressure may decrease the ignition temperature of vapor from some lubricating oils to the point where the abnormally high temperature caused by a leaky discharge valve would cause spontaneous ignition.

The next question which the author considered was how may sufficiently rich mixtures accumulate to provide for a violent combustion explosion. The answer will be found in the original article. (Wm. D. Halsey, Asst. Chief Engr., Hartford Steam Boiler Inspection and Insurance Co., in the *Locomotive*, reprinted in *Boiler Maker and Plant Fabricator*, vol. 34, no. 11, November, 1934, pp. 292–294)

ENGINEERING MATERIALS

Lead-Base Bearing Metals

THE author refers to researches in the United States, particularly at the Westinghouse Electric & Manufacturing Co. in 1918, on various lead, tin, antimony, and copper alloys.

In studying the lead-base bearing alloys it was soon found that the various chief disadvantages of these metals as compared with the tin-base alloys, the lack of strength, ductility, bearing capacity, and resistance to wear, were not really due to inherent weaknesses, but to the fact that the age-old experience with tin-rich alloys had been applied in a more or less haphazard way to the compounding and handling of the lead-rich alloys.

The author believes that the standard lead-copper alloys with 5 per cent of tin and 15 per cent of antimony are well adapted for general machine bearings.

Among the various advantages over the tin-rich bearing metals claimed for these alloys is the comparatively low degree of sensibility toward small temperature changes. Both the carrying capacity and the chief technological properties are less influenced in this respect than in tin-rich metals. It is a well-known fact, therefore, that if alloyed, poured, and treated correctly, the lead-rich bearing metals of this composition will show less fluctuation of properties under practical working conditions than the tin-rich materials, although with sudden increases of heat, requiring a rapid heat conduction, the latter are believed to be more satisfactory, a fact chiefly due to their higher coefficient of thermal conductivity.

Lead-rich alloys are more sensitive to influence of pouring temperatures than tin-rich alloys and some practical suggestions are given in the original article. Preheating, pouring practice, and precautions to be observed during cooling are also discussed, and a list of lead-tin antimony alloys is given. (E. T. Richards in *Metal Industry*, London, vol. 45, no. 23, Dec. 7, 1934, pp. 533–535)

Beryllium Alloys

THE author deals primarily with beryllium alloys of heavy metals, such as copper and nickel, and states that these alloys belong to the class of alloys whose physical characteristics may be controlled to a certain extent by heat treatment. This includes principally alloys of copper with 2.5 per cent beryllium, nickel with 1.7 per cent, and contracid with 0.6 per cent. (Contracid is an alloy containing approximately 60 per cent nickel, 15 per cent chromium, 7 per cent molybdenum, the rest being iron with small additions of manganese and silicon.) Fig. 1 shows the physical characteristics of the alloys as a function of their heat treatment.

If a chipless process (such as rolling, drawing, pressing) is introduced between the quenching from the high temperature and tempering, the physical characteristics of the metal may be still further improved. Fig. 1 also shows the influence of cold-working with appropriate heat treatment. From this it would appear that the strength of a beryllium-copper alloy, equal to about 60 kg per sq mm in the soft annealed state, may be raised by cold-working and appropriate heat treatment to about 130 kg per sq mm;

the corresponding figures for the beryllium-nickel alloys are from 80 to 180, and for beryllium contracid 90 to 190 kg per sq mm. It is noted also that these heat-treatable beryllium alloys combine a comparatively high elongation with a high tensile strength. For example, the beryllium nickel gives a 7 per cent elongation with tensile strength of 185 kg, and beryllium contracid gives a 3 per cent elongation with 192 kg per sq mm. Beryllium alloys are therefore particularly applicable where a drawable material of great hardness and high elongation is desired. It is natural in annealing with temperatures of from 200 to 500 C that the elongation, due to heat treatment, increases as compared with the cold-worked state, so that simultaneously with an increase in the strength of the material the stresses residual from the working processes disappear.

It is important to call attention to the fact that the heat treatment also improves the elastic properties of these alloys. While as a rule the coefficient of elasticity of an alloy is comparatively little affected by heat treatment, in the case of the heat-treatable alloys, and particularly heat-treatable beryllium alloys, heat treatment brings about a material increase in the coefficient of elasticity. Beryllium-contracid alloy may be mentioned as an example, as here the modulus of elasticity in the soft annealed state is about 15,500 kg per sq mm, while in the cold-worked and heat-treated metal it is 18,500 kg per sq mm.

Fig. 1 gives the average values obtained with the best kind of treatment for the corresponding alloys and methods of treatment. In actuality, all kinds of intermediate stages of mechanical properties can be obtained by variation of heat treatment. This is shown in Fig. 2, dealing with Brinell hardness of beryllium copper. It shows the functional relationship of Brinell hardness to the duration of heat treatment at various temperatures. At low temperatures, such as 200 C, the increase of hardness is produced by a treatment lasting from 10 to 14 hr, or until the utmost hardness for that temperature is attained. The same is true for temperatures of 250 C, but at 300 C the maximum hardness of 360 Brinell is obtained in one hour, and after that the alloy begins to soften. At 350 and 400 C, softening sets in so rapidly that it is practically impossible to obtain the maximum value of hardness, and one might say that the softening begins midway. Similar curves for other properties have been obtained. From this it follows that all intermediate values between the soft and the very hard state can be obtained, but the proper method of heat treatment for every individual purpose is to be determined. Fig. 3 in the original article gives curves showing the variation of electrical conductivity and volume for different treatments of a beryllium-copper alloy with 2.5 per cent of beryllium. Other illustrations show the grain structure of beryllium-copper alloys and fatigue strengths of beryllium and phosphor bronzes. These latter have been taken from the work of Illig and Fischer.

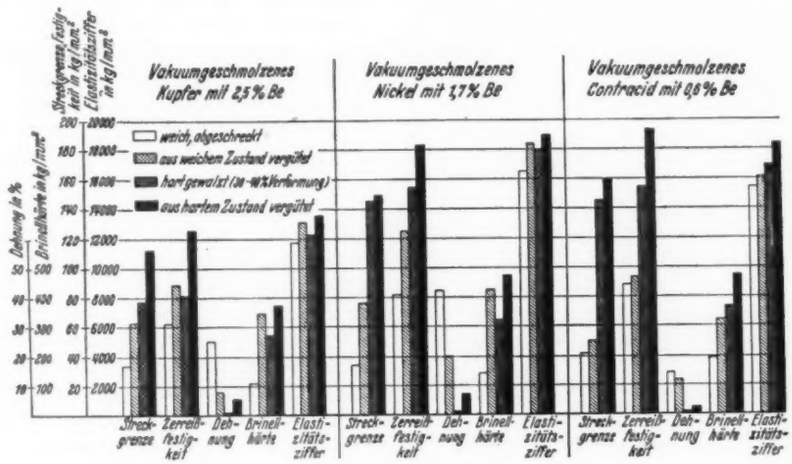


FIG. 1 INFLUENCE OF HEAT TREATMENT ON THE PHYSICAL PROPERTIES OF BERYLLIUM NON-FERROUS ALLOYS

(*Dehnung in %* = elongation; *Brinellhärte in kg/mm²* = Brinell hardness; *Streckgrenze Festigkeit in kg/mm²* = yield point; *Elastizitätsziffer in kg/mm²* = modulus of elasticity; *Vakuumgeschmolzenes* = melted in vacuo; *Kupfer mit 2.5% Be* = copper with 2.5 per cent beryllium; *Nickel mit 1.7% Be* = nickel with 1.7 per cent beryllium; *Contracid mit 0.6% Be* = contracid with 0.6 per cent beryllium; *weich, abgeschreckt* = soft, quenched; *aus weichem Zustand vergütet* = tempered from soft state; *hartgewalzt (30–40% Verformung)* = hard-rolled (30 to 40 per cent deformation); *aus hartem Zustand vergütet* = tempered from hard state; and *Zerreissfestigkeit* = rupture strength.)

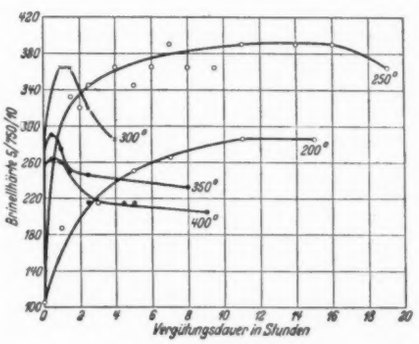


FIG. 2 HARDNESS OF BERYLLIUM-COPPER ALLOYS AFTER VARIOUS HEAT TREATMENTS

Because of the powerful affinity of beryllium for oxygen, nitrogen, sulphur, and other metalloids, the handling of these alloys must be done with extreme care, which applies particularly to the process of melting and casting. The use of the vacuum-electric furnace is recommended. (Dr. Eng. W. Hessenbruch in *Werkstattstechnik und Werksleiter*, vol. 28, no. 19, Oct. 1, 1934, pp. 378–381, 10 figs.)

FUELS AND FIRING

British Fuel Research Board's Report

AMONG other things the report points out that formerly large lump coal selected by hand at the picking belts was in great demand, because it contained the least ash and was relatively easy to handle. Great strides, however, have been made in the purification and grading of small sizes of coal, and now more than 77,000,000 tons of coal are cleaned per year in Great Britain either by washing or dry-cleaning processes. The result is that there is now less demand for large coal and an increased demand for small coal. Improvements in washery cleaning of coal brought about increased economy in the use of the water and recovery of fine coal from the waters. In addition they prevent the deposit on the coal of dirt in the form of clay-like material, to the detriment of its appearance.

Much of the report is devoted to the extraction of motor spirits and fuel oils from coal. It is mentioned that during the year 1933 one Home Defense Squadron of the Royal Air Force flew solely on motor spirit produced from coal. The

results have been so satisfactory that a contract has been placed to cover the requirements for seven squadrons. The Royal Navy is also experimenting with oil produced from coal.

The experiments with pulverized coal at the Fuel Research Station are being directed mainly to a study of the principles underlying its combustion and the object of developing methods by which coal can be burned in this form in boilers with small combustion spaces, such as Lancashire or marine-type boilers. The difficulties arise when the coal contains less than 20 per cent volatile matter, as is the case with many excellent "steam" coals available, especially in South Wales and Scotland (about 15 per cent volatile matter).

Another important point, especially for marine purposes, is flexibility of the burner as regards the degree of fineness to which the coal must be ground. Three types of burners have been devised at the station, and one, the "Grid" burner, is already being manufactured by a commercial firm.

Consistently good reports are being received concerning industrial application of this burner and particularly gratifying results appear to be obtained with it when applied to small metallurgical heating furnaces using a maximum of only 80 lb of coal per hr. It is claimed that not only is the general operation at least as good as is obtained in similar furnaces with oil, but the fuel consumption is lower in heat units as well as in cost.

The largest burner in use at present consumes about 1600 lb of coal per hr, but an order has been accepted for a plant in which three tons of coal will be consumed per hour in a single burner. (*The Steam Engineer*, vol. 4, no. 4, January, 1935, pp. 137–138)

INTERNAL-COMBUSTION ENGINEERING

Future Prospects of the Coal-Dust Burning Motor

IT IS CLAIMED that the difficulties of fuel feeding and quick ignition have been successfully overcome by the use of a fore-chamber. It is also said that with good combustion and right feed in the cylinder the residue passes out with the exhaust almost completely, any residue not so passing being removed by scavenging.

The principal difficulty is the rapid wear of the moving parts, but through suitable construction and the use of special materials, it is possible to reduce the wear to the extent that the life of the bushes, piston rings, and valves amounts to about 10,000 working hours, and a better figure may be expected.

As regards selection of fuel, it is important that ignition of the fuel should occur at the lowest possible compression temperature, and the ash must be quite low to avoid excessive wear. Extremely fine milling of the fuel has been found to be unnecessary. The first cost and the operating and depreciation costs are higher for a coal-dust motor than for an ordinary Diesel motor of equal performance.

Nevertheless the coal-dust motor is claimed to be economically superior to the oil-fed Diesel. Further work is required on the motor to increase reliability. (Paper by Dr. of Engrg. F. Schulte at the Sixth Technical Conference of the Ruhr Coal Mining Industry, abstracted through *The Fuel Economist*, vol. 10, no. 111, December, 1934, p. 619)

Coal-Tar Oils in Internal-Combustion Engines

THIS is an abstract of a report to the General Research Committee of the Institution of Gas Engineers and presents a summary of the experience so far gained in the use of coal-tar oils in internal-combustion engines based on reports or answers to a questionnaire sent out to British manufacturers and users. The report is concerned mainly with the use of tar oils in the spark-ignition engine, but deals also with their use in engines of the compression-ignition type. The application of these oils to spark-ignition engines is recent, having been developed mainly as a result of work initiated in 1929 by J. D. Smith of the Belfast Corporation Gas Department in collaboration with other companies.

From this report it would appear that suitable arrangements for the proper vaporization of the fuel are required in order that tar-oil fuels may be successfully used in mobile spark-ignition engines and that castor oil has been found to be the most suitable lubricant. Careful preparation of the fuel is essential and specifications laying down the requirements which the fuel must meet have been established. The use of tar-oil fuels is attended by a number of drawbacks which are discussed in the report, though the fuel cost is considerably less than when gasoline is employed. More skilled attention on the part of the drivers and the garage mechanics is required than is the case with gasoline-driven vehicles. In general, tar-oil fuel has been employed for starting up and for idling.

The ratio in which the two fuels are consumed depends on the nature of the journeys undertaken, the tar-oil gasoline ratio being low on short journeys with frequent stops and high on long distance work. The use of tar-oil fuels adds to mechanical troubles and, in most cases, increases maintenance costs.

In so far as mobile spark engines are concerned, the measure of success obtained in the use of tar-oil fuels as a substitute for gasoline has been but partial, though much experience has been gained and might pave the way to ultimate success if further work were carried out conjointly by the car manufacturers and the carbonizing industry. The scope for such a fuel is limited by the comparatively small quantities which could be made available. In stationary engines of the spark-ignition type, results are much more promising since conditions are less exacting.

Tar oils are inherently unsuitable for use in the standard types of compression-ignition engines, though improved methods of atomization, the use of ignition catalysts, and the use of pro-knock compounds are possible means for overcoming the drawbacks attached to these oils. The admixture of a certain proportion of an ordinary Diesel fuel oil with tar oil may also provide a solution.

As regards specifications for coal-tar oils to be used as fuels, some are given in appendixes to the original report. The vital feature of the specifications is the limitation of the amount of carbon residue in the Conradson test. To secure compliance with this clause either very good fractionating equipment or repeated distillation is necessary. The carbon residue may increase during storage of the fuel.

It is difficult to understand why the recommended viscosity of 27–28 sec in the Redwood instrument at 100 F was chosen. Such a rate of flow is commonly regarded as outside the useful range of this instrument, and different viscometers of this type are liable to considerable variations when the efflux time is as low as this. It would have been better had a longer time of outflow and a lower temperature been specified.

In so far as mechanical troubles are concerned, consideration must be given to gumming of the valves or plugs, soot on the plugs, overheating troubles, and abnormal wear. Methods of overcoming this are mentioned. (H. M. Spiers and E. W. Smith, report abstracted through *Gas Journal*, vol. 207, no. 3722, Sept. 19, 1934, pp. 642–649, none of the appendixes of which there are eight is given in the abstract in *Gas Journal*)

Measuring Atomization in Fuel Nozzles of Diesel Engines

VON SAUTER, in 1926, developed an optical process by which the average fineness of atomization produced by carbureters could be measured. In this case the average fineness of atomization is so defined that instead of considering the actual mixture of air and droplets consisting of droplets of widely varying diameters flowing past the observation post, a substitute uniform mixture is introduced, which has the same total volume of fuel V in cubic centimeters as the droplets actually present in the mixture and also has the same total area of surface of the droplets O (in square centimeters) as the material contained in the mixture measured. The Sauter process permits the determining of the radius of the droplet of the substitute mixture $r_m = 3\ V/O$ (cm.). This equation defines the average radius of droplet in the actual mixture.

In order to determine r_m, it is merely necessary to know, first, the amount of fuel B in cu cm per sec passing in front of the observation post with a velocity w in cm per sec and, second, the amount of light U, absorbed by the liquid flowing in front of that observation post as a percentage of the beam of light going through the fuel tube. Assuming that all the conditions limiting the precision of measurement have been properly taken into consideration in operating the device, r_m can be calculated from the following formula

$$r_m = K \frac{B}{u} \frac{1}{w} \quad \ldots\ldots\ldots [14]$$

In this case K is a characteristic constant of the apparatus used and u is a function of the value of absorption of light U as determined by measurement, namely

$$u = f(U) = -100 \ln \left(1 - \frac{U}{100}\right) \quad \ldots [15]$$

In calculating the radius of droplet from Equation [14], it is assumed that all fuel particles flow with the velocity w. Sauter, in his tests on carbureters, has selected the distance of the observation post from the nozzle of the carbureter in such a manner that the droplets are accelerated to practically the same velocity as the air stream carrying them, so that, in Equation [14], $w = w_l$, w_l is the velocity of flow of the air stream, selected for this distance 400 mm. In the case of Diesel nozzles, because of the enormously great retardation of the jet in the immediate proximity of the nozzle, measurements by optical means are impossible. Nevertheless, contrary to an assumption made elsewhere by Sauter, the velocity of the jet approaches the zero value only after the jet has passed through a great distance, which means that it is only then that the velocity of the fuel particles themselves w_b may be neglected as against the air velocity w_l.

A brief consideration of the tests made by Sass on the penetrative power of fuel jets shows that in the case of jets in calm air, even after a depth of injection of 300 mm, the tip of the jet has a very slowly decreasing velocity of flow of its own w_b, depending on the injection pressure and counter pressure and amounting to from 6 to 20 m per sec. If, therefore, it should be decided to place the observation post where w_b becomes equal to zero, comparatively great distances from the injection nozzle will be required, and the air velocity w_l will have to be considered as being additive to the velocity of the fuel, namely

$$w = w_l + w_b \quad \ldots\ldots\ldots [16]$$

and this will still further increase the distance from the nozzle to the observation post. With very great distances between the nozzle and the observation post it becomes doubtful whether the fineness of atomization as measured is the same as is present in the natural engine where the distance of flow of fuel is very small. Heretofore, it has not been possible to measure the velocity proper of the fuel in the case of steadily flowing atomization jets. If the Sauter principle of measurement should be employed it can be done only in a form which suits given conditions.

Should one measure r_m under otherwise similar conditions but with the application of two different velocities of air, w_l and $w_l + \Delta w_l > w_l$, it will be found that the velocity of the fuel particles w_b, with the same distance from the nozzle to the observation post, will require in the second case a larger value, $w_b + \Delta w_b$, which is due to the fact that the time available for covering that distance in the second case is shorter. The value of B/u in the second case will have to be increased by $\Delta B/u$. A double application of Equation [14] ultimately gives

$$w_b + w_l = \frac{B}{u} \left[\frac{dw_l}{d\frac{B}{u}} + \frac{dw_b}{d\frac{B}{u}} \right] \quad \ldots [17a]$$

and

$$r_m = \frac{K}{\frac{dw_l}{d\frac{B}{u}} + \frac{dw_b}{d\frac{B}{u}}} \quad \ldots\ldots [17b]$$

A brief orientating calculation will show for an example the error produced by neglecting $dw_b/d\frac{B}{u}$ in Equation [17b]. The numerical values are here taken from the injection tests made by Sass. The average velocity of the fuel particles alone during the first $^5/_{1000}$ second at the injection pressure of 300 atm gage is given as $w_{bm} = 120$ m per sec, while the true retardation of the tip of the jet is $\frac{dw_b}{dz} = -3000$ m per sec per sec. Sass carried out two tests with air velocities of 2 and 3 m per sec. The distance of the observation post from the nozzle was 0.6 m, and this was covered in the time

$$z_1 = \frac{s}{w_{bm} + w_{l1}} \text{ or } z_2 = \frac{s}{w_{bm} + w_{l2}} \text{ sec.}$$

When the numerical values had been inserted in the proper equations, it was found that the difference in time in the passage before the observation post by equal drops in the two tests, amounted to $z_2 - z_1 = 5 \times 10^{-5}$ sec. In this time, the velocity of the fuel particles alone has fallen off by the amount

$$dw_b = -b\ dz = -3 \times 10^3 \times 5 \times 10^{-5} = -0.15 \text{ per sec.}$$

As compared with the absolute magnitude of the velocity of the flow of fuel, this amount can be neglected, which means that a calculation with $w_b = \text{const}$, and hence $dw_b/d\frac{B}{u} = 0$ is completely justified under the conditions of the test. The average radius of droplet can therefore be calculated from the following equation

$$r_m = K \frac{d\frac{B}{u}}{dw_l} \quad \ldots\ldots [17c]$$

The error induced by the use of Equation [17c] obviously becomes smaller as the velocity of motion of the fuel particles approaches zero. This is because it tends toward this value asymptotically as shown by the diagrams representing the penetrative power of the droplets. For $w_b = 0$, correct values of r_m can be obtained from Equation [16] in accordance with Equation [14] by stating $w = w_l$. From tests made in 1934 and evaluated in accordance with the process here described, B/u was plotted against w_l and always gave a linear relationship between these two groups. In this way the applicability of Equation [17c] was confirmed. The injection pressures which were used in these experiments ranged from 60 to 160 atm gage. Fuel

velocities determined from r_m for purposes of control by means of Equation [14] lay, in accordance with test conditions, in the range from $w_b = 0.7$ to 7.0 m per sec. With such a widely ranging retardation, the assumption that there was sufficient equalization of velocities in the individual cross-sections of the jet was justified, and forms one of the basic assumptions for this process of measurement. (Hans Mehlig, communication from the Institute for Combustion Prime Movers and Technical Thermodynamics of the Technical High School in Hanover, abstracted through *Zeitschrift für technische Physik*, vol. 15, no. 9, 1934, pp. 360–361)

LUBRICATION

Duration of Effectiveness of Colloidal-Graphite Lubrication

TESTS made in Germany with colloidal-graphite lubrication dealt primarily not with the use of graphite for running in engines but its use in continuous operation, the question to be answered being: For how long will an addition of colloidal graphite to lubricant last in effectiveness? The details of the tests are given in the original article. Among other things, it is stated that these tests were carried out on a divided bearing 70 mm in diameter and 80 mm wide having a high-grade white-metal lining (75 per cent tin) and an unhardened shaft brought to a high degree of smoothness. The results are given in the original article in the form of curves and comprise the coefficient of friction as a function of peripheral velocity with lubrication by pure oil and graphitized oil. Another gives the time variation of the coefficient of friction during and subsequent to the addition of graphite at two speeds, for a single addition of graphite at 72 rpm and repeated additions at 51 rpm. The last set of curves shows again the variation of coefficient of friction as a function of peripheral velocity when the device was lubricated by pure oil applied after a prolonged operation with additions of graphite.

Tests are said to have indicated the beneficial effect of additions of graphite, and the persistence of this effect. It has been found, however, that when the supply of graphite has been cut off the higher coefficient of friction appeared quite rapidly, though here again the friction itself seems to be lower than it was before graphite was introduced for the first time. On the whole these experiments seem to indicate that a distinction should be made between a rapidly passing effect of graphite additions and a persistent effect. It is stated that although the bearings after several careful runs have been so well run in that when lubricated by pure oil for more than 100 hr of operation there has not been found even the smallest variation of friction. The values for the coefficient of friction were always lower than before when the bearing was run with graphite for 40 hr and the graphite additions were cut off thereafter. The reduction in friction, however, though persistent, amounted to only one-third to one-quarter of that which was observed while the graphite addition was in effect. It is said, therefore, that a really effective reduction of friction can be obtained only by having graphite constantly added to the lubricating oil, as even when the addition of graphite was interrupted for only a very short time for half an hour the friction increases materially. (O. Walger and Dr. of Engrg. H. von Schroeter, Communication from the Machine Laboratory of the Technical High School in Karlsruhe, published in *Petroleum Zeitschrift*, vol. 30, no. 32, Aug. 8, 1934, pp. 2–4, 2 figs.)

MACHINE PARTS

Quill Bearings for Aircraft

THE quill bearings consist of an inner and outer raceway, rollers, and hardened side plates or lips. The inner raceway may be a separate part or a shaft and the rollers are of small diameter in proportion to the shaft diameter and of great length with respect to roller diameter. The carrying-capacity formula is given in the original article. The carrying capacity of these bearings depends upon the hardness of the bearing elements.

The data as to proportion of rollers are also given in the original article, the roller diameter being a function of roller speed and number of rollers for a full complement; where possible, this number should be kept under 60 rollers per row. Roller speeds "theoretically" greater than 60,000 rpm should be avoided, although successful applications have exceeded these values. "Theoretical roller speed" is obtained from the ratio of the shaft diameter to the roller diameter multiplied by the shaft speed in rpm. A figure in the original article shows the types of ends used on quill-type rollers and the effective length to be used in calculating the carrying capacity. Data are given showing how to determine approximately the proper number of quill rollers and clearances. Data are also given on retaining rings. (H. D. Allee, Bantam Ball Bearing Co., in *Aero Digest*, vol. 25, no. 5, November, 1934, pp. 30–32, 7 figs.)

MARINE ENGINEERING

Simplex Unit Marine Geared Steam Turbine

IN THIS turbine the cost has been reduced to about that of a modern reciprocating engine with poppet valves, operating on superheat, while at the same time there is a large saving in weight. Moderate steam pressures have been adopted so that Scotch or other ordinary boilers can be installed, and all valves, steam pipes, etc., can be provided to the usual standards. No new principles are embodied.

The set built by the Parsons Marine Steam Turbine Co. consists of a high-pressure and low-pressure turbine in series, both working on the same pinion for the sake of simplicity. (In units with a capacity in excess of 2000 shp there would be separate pinions.) The high-pressure turbine has a two-row impulse wheel followed by three stages of end-tightened blading which is said to reduce leakage to a minimum. Incorporated in the high-pressure casing is a double-row impulse wheel to serve as a high-pressure astern unit. This runs normally in a vacuum.

The high-pressure rotor is coupled to the pinion by a flexible coupling and is provided with a Michell thrust bearing. On the forward side of the pinion and connected to it by a flexible coupling is the low-pressure turbine with Parsons blading throughout and a low-pressure astern unit fitted in the same casing. The double-reduction gear is of the single helical type reducing the turbine speed of 4000 rpm to the propeller speed of 80 rpm.

The condenser is placed under the low-pressure turbine and the whole plant is so arranged and connected together that it can be lowered as a single unit on its setting on the tank top and it is merely necessary to set the main gearwheel shaft in line with the propeller shaft.

On the bedplate with the turbines, gear box, and condenser, an auxiliary unit is arranged. This embodies the circulating, extraction, oil, bilge, and sanitary pumps. This unit is normally driven by a chain from the main shaft through a clutch, but for starting or maneuvering a small reciprocating engine is provided, which also drives the set through a clutch. The pumps can be run by this engine when starting up or when maneuvering. When running nor-

mally at sea the engine is cut out and the economy due to a drive from the main turbines is secured. It is proposed, further, to drive a dynamo from this auxiliary unit with a voltage regulator to allow for the variation in speed of the main engine.

The results of tests of the unit are reported in the original article. It is expected that it will show a consumption of less than 1 lb of coal per ihp-hr. (*Engineering*, vol. 138, no. 3598, Dec. 28, 1934, pp. 706–707, illustrated)

METALLURGY

Flakes in Forgings

VARIOUS views on the origin of flakes in forgings are presented. It is said that the best method of prevention is to make sure that the forging cools very slowly and equally through the split transformation. Work should be stopped at 1600 F and the completed forging returned to a preheated annealing furnace, the temperature equalized, and then allowed to cool slowly to 500 F in the sealed furnace, reheated to 1600 to 1650 F to refine the grain, and again cooled in the furnace to room temperature. Although little if any dispersion of the inclusions in the crystalline boundaries takes place during such a "normal" heat treatment, the brittle carbides are broken up and diffused, removing all subsequent danger.

Any forging known to contain flakes will redevelop flakes after forging if still above 3 in. in cross-section and allowed to cool uncontrolled from a forging heat. These flakes, however, are not the original defects, but a new crop which have developed after the final forging operation. The original ones, providing they were not exposed to any oxidizing influence during heating, would have welded perfectly and been undetectable under any known means of investigation. (H. H. Ashdown, Consulting Metallurgist, Pittsburgh, Pa., in *Metal Progress*, vol. 26, no. 2, August, 1934, pp. 26–29, illustrated)

MOTOR-CAR ENGINEERING

Self-Refrigerated Trucks

IN THIS system, the fuel, which is a liquid called "petrogas" is carried in a steel cylinder under a pressure of about 125 lb per sq in. Evaporation of the fuel as it passes through a throttle valve on its way to the engine cylinder absorbs heat, thereby producing refrigeration. The fuel evaporates a saturated gas of approximately 5 lb per sq in. During evaporation the latent heat of vaporization, which amounts to approximately 180 Btu per lb of fuel, is absorbed from the cooling unit. The cold dry gas then passes through a heat exchanger where it absorbs heat from the incoming liquid fuel and then goes through two diaphragm regulating valves, where, in two stages, the pressure is reduced to atmospheric. After passing through a mixing valve the gas then goes into the intake manifold of the engine.

Petrogas is marketed at approximately the same price as gasoline on a performance basis. It has the advantage of eliminating dilution of crankcase lubricating oil. (*Product Engineering*, vol. 5, no. 8, August, 1934, p. 286, *d*)

POWER-PLANT ENGINEERING

Steam-Turbine Regulation

THIS invention applies to a mechanism for regulating prime movers for the drive of alternating-current generators in electric power-transmission systems (Fig. 3). *A* indicates a centrifugal speed governor on the prime mover, and *B* a synchronized motor which is controlled at a constant speed by a standard clock through the conductors *C*, and which is driven, for

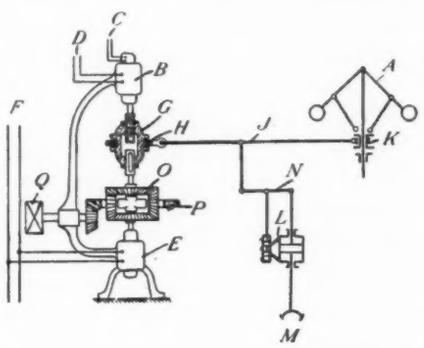


FIG. 3 ELECTRIC POWER TRANSMISSION REGULATING SYSTEM

example, by a direct-current source through the conductors *D*. The network clock comprises a synchronous motor *E* connected to the network *F* of the machine to be regulated and rotating with the frequency of this system. *G* is the main differential of the regulator, the movable central sleeve of which is rotatably seated in a ring *H* pivoted to the free end of the control lever *J* of the prime-mover control. The sleeve is connected non-rotatably with the shaft of the motor *E*, but is able to slide axially thereon. The connection of the sleeve with the motor *B* is effected through a spindle thread. If the speed of the two motors *E* and *B* is the same, then the sleeve of the differential *G* is merely taken round without displacement from the central position. If a difference occurs between the two speeds, then the sleeve is displaced either upward or downward, whereby the control lever *J* is swung either upward or downward about the pivot point at the sleeve *K* of the speed governor *A*. Thereby, the control slide of the valve gear *L* is moved and the main admission valve *M* is either opened or closed. *N* is the return rod provided in the known manner for the control valve. Besides the differential gear *G*, an additional gear differential *O* is provided, and the planet wheel spindle carries a toothed rim *P*, which can be rotated through the gear *Q* by hand or in dependence upon output. Thereby the sleeve of the differential gear *G* can be raised or lowered as required, and thus the admission to the prime mover can be changed. (British patent, no. 419,146, Nov. 2, 1934, International General Electric Co., New York, N. Y., in *The Engineer*, vol. 159, no. 4121, Jan. 4, 1935, p. 29, 1 fig.)

University of Texas Power Plant Extension

IT IS claimed that a 155 per cent increase in load has been made with but 39 per cent increase in expenditure. A series of unusual circumstances, including the discovery of oil on land with which the University of Texas had been endowed, produced a revenue which in 1931 was sufficient to enable the institution to finance a $5,000,000 building program without the use of any funds produced by taxation.

This caused an increase in demand for steam to a value exceeding twice that of 1928. The engineers estimated that the amount of steam to be consumed was to be trebled and the amount of power required doubled, a problem all the more difficult as it was decided that the fuel-burning equipment should be designed to consume lignite, a native Texas fuel. At that time little information was available concerning the burning characteristics of this material as a grate-fired fuel, of which 35 per cent by weight is moisture. While the fuel was used successfully before, calculations made for the design of the new equipment revealed the fact that materially higher efficiencies could be expected with proper design. The details of this calculation are stated in the original article.

In the latest installation a traveling-grate stoker is used. An interesting ar-

rangement has been devised to overcome admission of excess air to an extent greater than desired, particularly at fractional loads. A new control panel has been designed which shows the operator the steam and feedwater pressures and temperatures, drafts at six different stations, temperatures of air and gases entering and leaving the air preheater, stoker and fan speeds, and CO_2 content of the flue gas, as well as the flow of feedwater, steam, and combustion air.

A table and a chart in the original article show the extent of reduction in production costs as a result of the installation of new equipment which are quite impressive. The rate at which reductions in unit production costs are being made is said to justify the belief that additional economies can yet be effected. (Carl J. Eckhardt, Jr., Supt. of Power Plants, University of Texas, in *Southern Power Journal*, vol. 52, no. 12, December, 1934, pp. 16–22, 13 figs.)

Single-Tube or Flash Boilers

IN A PAPER before the Junior Institution of Engineers, W. James Calderwood claimed that the economic pressure for a moderate-sized boiler of the drum type appears to be of the order of 500 to 600 lb per sq in. and for very large boilers about 1000 lb per sq in. As regards flash boilers of the earlier types he claims that the chief difficulty was that of regulation and the tendency to throw over water with the steam if there was a sudden increase of load on the boiler, with the corresponding tendency to overheat at the outlet if there was a decrease in load.

Some time ago the author's firm started a series of experiments, first on an oil-fired boiler and then on coal-fired boilers. It was found that it was necessary to have sufficient velocity through the tube to insure that as steam is generated the bubbles of steam form a froth with the water and do not adhere locally to the walls, causing overheating. Experiments show that for this velocity it was necessary to have a very high ratio between tube length and diameter if a reasonable rate of transfer was to be used. The actual best relationship was found to be about 30,000 to 1, or roughly half a mile per inch of tube diameter.

The rate of feed is regulated thermostatically from the steam temperature, the thermostat consisting of an oil valve box mounted in the steam pipe while the valve is connected by an Invar metal rod to a point about 8 ft on the pipe. The temperature-operated valve controls the feed regulator. It will be evident that if the regulation were only on the main feed there would be a considerable time lag due to the long period the water takes to pass through the pipe (about 2 min at full load). To get a quicker regulation the feed is divided, about 10 per cent entering the boiler at the position where almost the whole of the water has been converted into steam.

According to the type of service which the boiler has to perform, there may be a single thermostat controlling both the main feed and the bypass, or where more exact and sensitive control is essential, two regulators may be fitted, in which case the steam temperature regulates the bypass, and the temperature at entry to the superheater regulates the main feed. (*The Fuel Economist*, vol. 10, no. 111, Dec., 1934, p. 615, *d*)

Loeffler System of Steam Production

A PAPER on this subject was presented by S. McEwen before the Institute of Fuels and the Institution of Mechanical Engineers, Nov. 9, 1934. It gives a theoretical increase in efficiency of power generation with steam under the conditions as to temperature and pressure adopted in the Loeffler system, as compared with those theoretically obtainable with steam under conditions of temperature and pressure now generally in use.

Calculations show that with steam at a pressure of 590 lb per sq in. and at a temperature of 842 F, the steam consumption per kilowatt generated is 11.7 per cent greater than with steam at a pressure of 1900 lb per sq in. and a temperature of 896 F. For the purpose of this comparison, it has been assumed that with the lower pressure there is no economic advantage in interstage reheating, but steam would be bled from the turbine in two stages to heat the feedwater to 302 F. Under the Loeffler conditions of higher pressure, reheating is adopted, and steam leaving the first stage of the turbine is reheated by means of a heat exchanger from 537 to 662 F. For preheating, the feedwater steam is withdrawn from the turbine in three stages, raising the temperature of the feedwater to 392 F. This increased degree of preheating by means of bled steam is warranted by the higher boiling point of the water at the higher pressure. The boiling point of water at 590 lb pressure is 486 F, whereas at 1900 lb pressure it is 623 F. The comparison allows for a higher power consumption for an auxiliary plant with the Loeffler system. The feed pump must, of necessity, owing to the higher pressure, require more power, and the steam-circulating pump has no place in the low- or medium-pressure system. Actually, the reduced steam consumption and the reduced weight of fuel to be handled secure a reduction in the power required for auxiliaries other than those of the feed and steam-circulating pumps; but for the purpose of this comparison an additional 3 per cent of the power generated has been debited against the Loeffler system, being the extra power required for the feed and steam-circulating pumps.

The increase in efficiency shown to be theoretically possible is of a substantial character, and as it can be obtained without being subject to a debit for increased capital and other costs, an equally substantial economy will be secured from commercial operation.

The success of the Loeffler system is ascribed primarily to four main characteristics of the system. Steam is the only medium for absorbing the heat which is liberated in the furnace and this steam in a very dense condition is caused to flow through tubes at a velocity which insures a small differential in temperature between that of the steam and the metal walls of the tube.

Under the conditions existing in the engine more than 40,000 Btu are transmitted per square foot of heating surface per hour through the surface of the radiant superheater without any risk of overheating the metal. The entire absence of scale or deposit on the interior surfaces of the tubes insures constant conditions for heat transference. There being an entire absence of water-circulation problems, the disposition of the heating surface can be arranged with consideration only for heat transmission. As tubes do not need to be cleaned internally, they can be disposed without regard to provision for cleaning. Furthermore, the high average rate of heat transmission which is actually obtained in practice, results in a material reduction in the area of heating surface which has to be provided for any given data, as compared with that required for a normal water-tube boiler. This reduction in area more than balances any extra expense per square foot of heating surface involved in providing for higher pressures.

The heart of the Loeffler system is the steam-circulating pump which is said to be simple in construction and very rugged. It is said that the steam pump, notwithstanding the power required for its operation, gives a real practical economy not fully appreciated when comparing guaranteed test performances of the Loeffler and water-tube boiler systems.

When testing a water-tube boiler and

turbine group, every effort is made to maintain the average steam temperature as closely as possible to that specified, but even then, in the majority of cases, the turbine manufacturers have to claim an allowance for the difference between the actual average temperature and that which was specified. In every-day operation this difference is usually greater, and over a period of a month's operation, the allowance for low temperature would be considerable.

Since it is possible with the Loeffler system to operate continuously, producing steam at the predetermined temperature, a high steam temperature may be adopted. It is not necessary to assume that under some extraordinary conditions the steam temperature may be higher than that desired. For this reason alone, a steam temperature may be adopted for the Loeffler system which is about 100 F higher than would be considered practicable with the ordinary system. The steam pump therefore effects its own economies; it more than pays for the power absorbed for its operation and for the capital charges which may be allotted to it. Expressed in another way, it may be said that if a device requiring as much power, and costing the same money, could be applied to a water-tube boiler system and succeed equally in maintaining uniformity of steam temperature, such a device would be a welcome extra in all such installations.

The greater reliability of the Loeffler system is reflected in the concessions which have already been granted in some countries in the regulations applying to feed pumps for steam boilers. The Loeffler boiler is practically independent of all continuous supply of feedwater. So long as any water at all remains in the drum, there can be no danger from overheating. In the event of the supply of feedwater ceasing entirely, there is sufficient water in the drums to enable the plant to be operated for a period of from 7 to 10 min, and this provides ample time to check the rate of combustion or to put a reserve pump into operation. It is in recognition of this element of safety that severity of the regulations referred to has been relaxed.

The flexibility of plant operation affecting the division between power and process steam is discussed and some data given on the Trebovice power station equipped with Loeffler boilers. In the discussion which followed it was pointed out that the Loeffler patents were to expire in about five months. Another speaker called attention to the application of the Loeffler boiler to locomotives. Criticism of several features of the system has been offered by the discussers. (*The Engineer*, vol. 158, no. 4114, Nov. 16, 1934, abstract of paper, pp. 494–496, 5 figs., and discussion, pp. 479–480; Compare *Engineering*, vol. 138, no. 3592, Nov. 16, 1934, original paper, pp. 546–548, illustrated, and discussion on pp. 535–536)

Ribbed-Tube Economizer for Horizontal Gas Flow

IN 1933 a reconstruction of an economizer twenty years old in the boiler plant of the Munich Technical High School was undertaken. This economizer was made up of smooth cast-iron tubes designed for a pressure of 14 atm gage and was installed so as to cool off the gases flowing from two of the boiler furnaces into the smokestack. Similarly to the Green economizers of that type the smokestack gases flowed in a horizontal direction, and as the velocity of flow of these gases was moderate, the economizer acted to some extent as a device for settling out the fly ash. The fly ash settled into the ashpit located under the economizer proper and was conveniently removed from there.

The ordinary designs of a ribbed-tube economizer would indicate a vertical direction of flow of gas with the bundle of economizer tubes standing either in the rising or the downward flow of the gases. In countercurrent setting, the water would flow opposite to the upward rush of the gases from top to bottom of the economizer. With the series connection of all the tubes and sufficiently high velocity of flow of water, this could be done without trouble. Whether, however, the flow of the smokestack gases was upward or downward, there was the disadvantage that the ashes would accumulate in the stack at a point from $1^1/_2$ to 2 m below the floor of the basement, and during the working time, could not be removed at all and could be removed only with considerable difficulty, even when the plant was not running. It was attempted, therefore, to overcome this defect by using a downward draft and by locating the economizer tubes at a greater height. This, however, gave such a tall structure that in order to install it, it would have been necessary to raise the roof of the plant which could not have been done as the building was of reinforced concrete.

Because of this it was decided to abandon the conventional vertical flow of gases of combustion and lead them horizontally just as was done in the case of the old smooth-tube economizer. It was recognized that there was a possibility that with such an arrangement there will be some reduction in the utilization of the heat as compared with the vertical-gas-flow economizer, but when the design for the new unit was worked out it was found that it required so little floor space, and, what was particularly important, so little height,

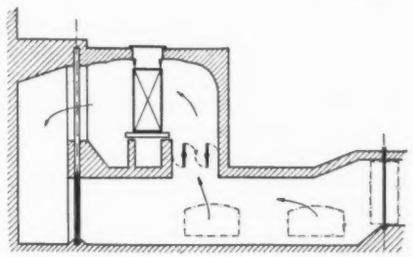


FIG. 4 GENERAL LAYOUT OF THE NEW RIB-TUBE ECONOMIZER WITH HORIZONTAL FLOW OF COMBUSTION GASES

that there was a very great saving in that respect, both over the old smooth-tube economizer and any possible design of a ribbed-tube economizer with vertical flow of gases of combustion. It so happened that great importance was attached in this case to the saving of room, and the university authorities decided that it was worthwhile to forego certain possible heat economies.

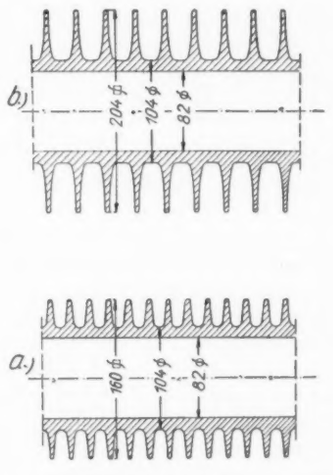


FIG. 5 ABOVE—TYPE *C* RIBBED ECONOMIZER TUBES; BELOW—IMPROVED TYPE *D* RIBBED TUBES

The new economizer, shown in Fig. 4, employs the tubes of the type *D* shown at *a* in Fig. 5, and for comparison, *b* is also shown in Fig. 5, the type *C* of ribbed tube of which type *D* is said to be an improvement. The new type has a lower rib height and a smaller pitch. The internal and external diameters of the

two types are shown in the drawings. The economizer consists of 78 tubes 2 m long and has a total heating area of 273 sq m; six tubes are located one back of the other in the direction of the flow of gases and 13 tubes in each row are located vertically. In order to provide for later increase in the output of the economizer there is room above the 13 existing rows of tubes for two more rows. At present this is covered over by deflectors. For cleaning the tubes from deposits of fly ash the economizer was provided with two soot blowers, one of which operates in the direction of the flow of gases of combustion, and the other at right angles to it, so that each tube is effectively acted on by the steam blast from all four sides.

As shown in Fig. 6, on the water side

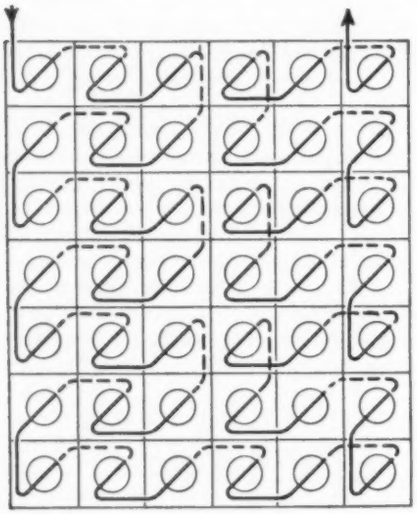


FIG. 6 DIAGRAM OF SERIES CONNECTIONS OF ECONOMIZER TUBES ON THE WATER SIDE

all the tubes are connected in series, so that at all loads there is a comparatively high velocity of water flow; this is done to prevent, as far as possible, deposits of sludges and the clinging of gas and steam bubbles to the walls. The water supply through the feed pump is led from top to bottom in the six rows of tubes located one after another. This water rises in the three front rows of tubes; the hotter part of the water stream has therefore an upward flow, so that at the higher temperatures the gas and air bubbles would be rising freely. For safety's sake, however, both behind the economizer and at the entrance thereto, a gas trap is provided. The water flows through it at a comparatively low velocity, and some water is blown off all the time from the highest point of the device.

The results of tests of this new economizer are reported in the form of a table, in addition to which curves are given showing the coefficients of heat transfer and draft loss at various velocities of flow of the gases of combustion, the latter varying from 4 to 10 meters per second. (M. Blümel in *Zeitschrift des Bayerischen Revisions-Vereins*, vol. 38, no. 18, Sept. 30 and Oct. 15, 1934, pp. 153–154 and 163–164, 5 figs.)

RAILROAD ENGINEERING

Light Freight Cars

THE Baltimore and Ohio Railroad has set up for freight cars a ratio of five to one, meaning five tons of revenue freight for every ton of deadweight in a car. The average ratio today is about two and a half to one. This problem was partially solved by increasing the size of equipment, which led to the development of a 95-ton steel hopper car and a sample all-welded hopper car of 70-ton capacity. Lighter materials have been introduced. For example, in 1934, a hopper car of aluminum alloy was built in which only the wheels, axles, brake beams, and cast side frames were made of steel. Next, two hopper cars were built of Cor-Ten high-tensile corrosion-resistant steel. Only the wheels and axles were made of conventional material. It is believed that these two cars are the first to be constructed anywhere of high-tensile corrosion-resistant steel.

The sides of both cars are of $^3/_{32}$-in. corrugated panel sheets with side sills $^1/_8$ in. thick. The materials are joined by riveting. The construction has demonstrated that an increase of eight per cent in the live-load capacity can be effected.

Freight-car corrosion is being carefully investigated, particularly with reference to the resistance of the material to the corrosive action of coal in the car, especially from mine water dripping from the coal, and atmospheric corrosion. The influence of loading on corrosion is also being investigated. The use of corrosion-resistant materials in freight cars is resorted to solely for the purpose of reducing the deadweight in rolling stock. (C. L. Lacher in *The Iron Age*, vol. 134, no. 12, Sept. 20, 1934, pp. 24–27, illustrated)

SPECIAL MACHINERY

Canadian Brass Mill

THIS article refers to a new rolling mill recently installed at New Toronto, Ont., by the Anaconda American Brass, Ltd. The mill is designed for rolling strips of much greater weight than have hitherto been rolled in American brass mills. The weight of the slabs is such that a furnace charge of 850 lb will fill either one or two molds, while a standard width of $18^1/_2$ in. has been adopted. Such a slab will produce 4-in. and 14-in. strips, 6-in. and 12-in., or any other desired combination down to two 9-in. strips.

A certain number of selvage strips are kept in stock to fill small orders. The mill is equipped with both hot and cold breaking-down mills for rolling strip metal from cake or casting down to 0.400 in., at which point it is overhauled and then cold rolled to finish. The cold mill contains many new features for handling heavy brass with a minimum of work. This cannot be described in detail because of lack of space. The big mill is a 14 in.–32 in. by 48-in. unit driven at constant speed of 200 ft per min by a 750-hp motor.

One of the most interesting features mentioned is the coil sticking machine. (Jas. R. Coe, Mech. Supt., American Brass Co. in *The Iron Age*, vol. 134, no. 13, Sept. 27, 1934, pp. 22–27 and 79, illustrated)

Automatic Forming of Elbows From Tubing

AS MANY as 3600 elbows which were normally cast at a relatively high cost are now formed from seamless brass tubing in the machine here described. A zigzag magazine is provided on this machine for fitting the pieces of tubing to the bending rolls. This kind of magazine permits an even flow of tubes without jamming and enables the operator to attend to several machines, all of which are entirely automatic.

The object in making the magazine of the zigzag type is to prevent the tubes from tilting as they pass down through it. Thus, if the operator inserts the tube in the top at an angle, when it strikes the first turn, it will straighten out. Moreover, if the machine is allowed to operate until only a few tubes are left in the magazine, and then more tubes are inserted, these will be deposited horizontally one upon the other, since, on the way down the guides, their position is corrected at each turn to a point close to the bottom. With a straight vertical guide, the tubes would be likely to "stack" at various angles. (J. E. F., *Machinery* (London), vol. 44, no. 1140, Aug. 16, 1934, pp. 577–578, 2 figs.)

SPECIAL PROCESSES

The Eloxal Process for Protecting Aluminum Against Corrosion

THERE is an interesting patent situation in this field. Several processes have been developed within the last few years for oxidizing aluminum, all of them being based on the application of special electrolytic processes, and there has been a good deal of overlapping of these patented processes leading to considerable confusion. Finally, the German concerns operating the Seo, Eloxal, and L.P.W. processes have entered into a cross-licensing agreement and were later joined by American and European concerns, with the exception of England and Russia. The American process involved was the Alumilite. In this way a complete security against patent litigation was provided and an exchange of experimental data secured. All these processes are known in Germany under the name of Eloxal and outside of Germany under the name of Alumilite.

The difference between electrolytic oxidation and electroplating lies in the fact that the protecting layer of the former is not deposited on the piece of metal but is produced by conversion of the surface thereof into an oxide or hydroxide. This occurs by an electrolytic treatment of articles to be protected in electrolytes subject to the operation of the valve action of the aluminum anode. As electrolytes are used more or less weak solutions of acids, such as chromic, oxalic, and sulphuric, with such additions as may be required for practical purposes, for example, nitric acid, potassium sulphate, malonic acid, and glycerine. The electrolytic treatment may be effected with direct as well as alternating current or by a combination of two currents. The opposite electrode where alternating current is used may be in the form of an article to be eloxided or a piece of an aluminum alloy. With direct current the article must consist of a material not affected by the electrolyte and this may be the case with alternating current.

There are three ways stated in the original article in which the oxidation may be carried out. The processes affecting the formation of a film on an aluminum article depend on the electrolyte selected, its concentration and temperature, the kind of current, the density of current, the potential, and the duration of the operation. The changes of temperature are particularly important in this process, which makes it especially necessary to maintain a correct temperature. The thickness of the layer produced can be controlled within wide limits by varying the duration of the treatment. An excessively long oxidation may unfavorably affect the hardness of the layer, and in many cases there is no advantage in carrying the process beyond a certain length of time for the purpose of obtaining a thicker protecting layer, as at a certain time a state of equilibrium is established between the velocities of formation and solution of the layer of oxide, and it may even happen that the process of solution comes to predominate, in which case the thickness of the film will be actually reduced by an excessively long treatment. By various additions to the electrolyte not only the properties of the electrolytes themselves can be varied but differences may be produced in the character and composition of the film of oxide, notwithstanding the fact that the basic material of the layer is always aluminum oxide. It has been established that certain anions may remain in the film and may even produce changes in the structure thereof. This offers an opportunity to vary the physico-technical characteristics of the film to improve its stability, appearance, etc.

The chlorine ion is dangerous as it attacks the metal. In the case of films which are glass-hard and very dense, the presence of gamma aluminum oxide has been established by X-ray tests. This material is crystalline and possesses an extremely fine grain. This is illustrated in the original article and proof is adduced that this material is not a hydroxide. The very hard and dense layers of oxide may be made soft and pliable by means of a subsequent treatment with steam, boiling water, or boiling salt solutions. Traces of electrolytes may be embedded in the oxide film, and, for example, in the case of films produced with chromic oxide, there are found in the film easily determinable amounts of colloidal chromium compounds. It is also possible to incorporate deliberately into the layer of oxide various compositions by means of addition of colloids or capillary-sensitive materials. This may be used for making the film suitable for certain special purposes. Particular mention is made of the use of colloids for closing up the pores in the layer of oxide and thereby improving its density and raising to an extraordinary extent its ability to protect from corrosion. From this it would appear that the conditions maintained in the oxidation, the selection of the electrolytes, and the additive materials have a powerful influence on the character and the properties of the film.

The article discusses the oxidability of aluminum and various aluminum alloys and the properties of the eloxal films. This has been determined by experiment described in the original article. It is stated that eloxal films when properly manufactured have a high ability to resist the effects of the atmosphere, plain water, sea and salt water, perspiration, dirt, factory dust, smoke, beer, wine, liquors, fruit juice, fats, herring brine, gasoline-alcohol mixtures, as well as a number of other chemicals and their watery solutions, for example, ammonium nitrate, ammonium sulphate, butyric acid, chromates and bichromates, concentrated organic acids, such as acetic and lactic, higher fatty acids, formalin, glycerin, potassium nitrate, calcium chloride, carbolic acid, photographic developing liquids and weak fixatives, sulphur, hydrogen sulphide, hydrogen peroxide, etc. An increase in the ability to resist corrosion can be accomplished in many cases by subsequent treatments. This can be done, for example, by filling the pores in the film by stable inorganic materials, such as silicid acid.

Data on electric resistance, reflection of light, and technical applications of the films, as well as details of various kinds of oxidation processes, are given in the original article. (H. Schmitt, R. Jenny, and G. Elssner, in *Zeitschrift des Vereines deutscher Ingenieure*, vol. 78, no. 52, Dec. 29, 1934, pp. 1499–1506, 17 figs.)

Sprayed Molten-Metal Coatings

THIS article deals with the development of the Schoop process (referred to in MECHANICAL ENGINEERING, March and September, 1932, pp. 214 and 658) as now represented by the "metalayer" process. It is claimed that with the standard spray nozzle used in this process held perpendicular to the surface being coated and 5 in. distant from it, the molten-metal spray covers a circle approximately 2 in. in diameter. A single pass over a surface sprays a metal coating of from 1 to 2-thousandths of an inch in thickness, depending on the metal being sprayed. Each additional pass increases the thickness of the coating by a like amount. The gun operates with oxygen and acetylene pressures ranging from 13 to 15 lb per sq in. and compressed-air pressure ranging from 45 to 55 lb per sq in., depending on the metal being sprayed and the application. Approximately 23 to 26 cu ft of oxygen, 22 to 25 cu ft of acetylene, and 2500 to 3500 cu ft of compressed air are consumed per hour per gun. Special nozzles have been developed for coating surfaces inaccessible with the standard nozzle.

Photomicrographs of sprayed molten-metal coatings show that they are made up of a multiplicity of plastic particles, which, by high velocity impact on the surface, are flattened out and interlocked, first with the microscopic open grain of the surface on which they are deposited, and subsequently with each other.

For maximum adhesion of sprayed molten-metal coatings to the base metal, a properly roughened surface is essential. The best method of preparing it is by sand or grit blasting, which also produces a chemically clean surface on which to spray the molten metal, which is essential for permanent adhesion and protection.

Metal coating costs are dependent upon a number of variables. Assuming average prices for oxygen, acetylene, and compressed air, the cost of these items will total about $0.80 to $1.30 per "metalayer" per hour, depending on the speed of operation. Wire costs may, of course, be determined from the price per pound and the number of pounds used per hour. The price of the wire per pound depends upon the metal which is being sprayed.

The cost of metal coating per square foot may be computed by dividing the total hourly cost by the number of square feet coated per hour. The latter is indirectly proportional to the thickness of the coating applied. Assuming a coating of six thousandths of an inch in thickness, which is developed by four to six passes and is a thickness frequently applied in actual work, the output per gun ranges from about 6 sq ft per hr for iron to about 60 sq ft per hr for lead. On this basis, the wire, gas, and compressed-air cost per square foot for 0.006-in. coating is about as follows: Iron, $0.18; lead or zinc, $0.11; aluminum, $0.09.

These figures do not take into account the "edge loss." Edge losses occur when the coating is done near the edge of a surface, as a portion of the molten-metal particles is sprayed past the edge and lost. On large surfaces the edge loss is a negligible percentage, but on small surfaces it is appreciable. Sand- or grit-blasting costs must be added to metal-coating costs to obtain the total cost for applications where such preparation of the surface is required. These are also variable, but as a rule do not exceed about $0.03 to $0.05 per sq ft.

Metal spraying is a valuable tool for repairing surface defects in practically any material, particularly with castings where sand-holes, blow-holes, and similar defects are apt to occur and cause rejection of the part. With metal spraying, iron, steel, bronze, aluminum, and alloy castings are reclaimed at small expense. The deposited metal may be readily machined or otherwise finished. Forged, drawn, and stamped pieces are repaired similarly. The surface is sand-blasted and repaired either before or after machining. A method of mass-coating small parts is described. (E. V. David, Air Reduction Sales Co., New York, in *The American Welding Society Journal*, vol. 13, no. 9, September, 1934, pp. 16–20, illustrated)

THERMODYNAMICS

Gaseous Specific Heats and Internal-Combustion-Engine Efficiencies

THE author presents calculations of theoretical specific heats largely taken from previous publications. These specific heats have been calculated upon the Planck-Einstein basis and are next compared with two other systems now in common use, namely, the Partington and Shilling system and the Pier and Bjerrum system. It would appear that the theoretical specific heats of the triatomic gases, carbon dioxide, and water vapor, are considerably different from the P. and S. and the P. and B. values. In the theoretical system the values for the diatomic gases H_2, O_2, N_2, and CO are widely different, whereas in the other system they are the same for these gases except in the case of H_2, the values for which are slightly different.

At temperatures up to about 600 C there is experimental work giving confirmation of the theoretical system which the author considers to be correct. He explains why the P. and S. values differ from the theoretical values.

The results of experiments made by the author and Dr. Smeeton Leah are given in a table. According to Partington and Shilling and Pier and Bjerrum, and others, the variations in the unaccounted energy or incomplete combustion is enormous. In the theoretical system the variation is very small, which is taken as a confirmation of the validity of this system. Experiments with argon as a main diluent gave somewhat uncertain results.

The author discusses flame temperatures and shows that the theoretical system of specific heats yields temperatures very much lower than those yielded by the Partington and Shilling system. He believes that the incomplete combustion (defining combustion in the sense of the overall process of conversion of chemical energy into internal or thermal energy) probably does not result from incomplete combination and has to do with latent energy in the flame gases.

The author's discussion of internal-combustion-engine efficiencies cannot be abstracted because of lack of space. In the case of high-speed non-injection engines (1000 rpm and over is specifically referred to), there has always been a doubt as to whether the measured indicated thermal efficiencies do not approach rather too closely to the ideal standard based on the Pier and Bjerrum specific heats, having regard to the more or less known losses which occur in these engines. There seems to be little doubt that they are too close to the new standard set up by the theoretical specific heats. Thus, efficiency figures shown in a table in the original article would indicate that the difference between the ideal and the measured efficiencies scarcely covers the loss in efficiency due to heat loss during the explosion-expansion stroke without taking into account such losses as those due to incomplete combustion.

One of the conclusions at which the author arrives is that were it possible to suppress all losses in the high-speed engines, their efficiencies would be greater than the ideal efficiency standards set up by the theoretical specific heats.

This somewhat startling conclusion suggests at once that the theoretical specific heats are far too high (just as flame temperatures suggest that they are far too low), but this, it is believed, is not the case. They may be, and probably are, subject to small errors, but these are almost certainly in the wrong direction, and in any case they would not affect appreciably the efficiency calculations.

Tentatively it is suggested that the probable explanation is that in high-speed engines the explosion process is so rapid that there is no time for the molecules of the diluent gases to attain their equilibrium share of intra-molecular (vibratory) energy, and they thus behave as though they possessed lower specific heats than their true specific heats under corresponding conditions of temperature. The experiments of Kneser lend interesting support to this suggestion.

In order to secure the highest efficiencies, in addition to high compression ratios, the aim should apparently be the building of the largest cylinders consistent with the highest speeds. An attempt to give a rational theory for this view will be made in a subsequent paper. (Prof. W. T. David in *The Engineer*, vol. 158, no. 4114, Nov. 16, 1934, pp. 476–478, 5 figs.)

LETTERS AND COMMENT

Brief Articles of Current Interest, Discussion of Papers, A.S.M.E. Activities

Wine Makers—Another View

To the Editor

The communication of Sanford A. Moss, published in your February issue,[1] was read by me with a great deal of interest, because I believe that he has raised a question which should be given the most serious consideration.

From the point of view of a research engineer, the criticism of Dr. Moss may be entirely justified, but do the responsibilities of an engineer begin and end with the study and application of engineering principles? Do they not extend to the ultimate effect of their application upon the welfare of humanity?

This is a question of great moral significance. If we answer it in the affirmative we can no longer look upon ourselves as a group of specialists, responsible only for the technical quality of our work, but as members of the community in whose hands has been placed a tremendous power for good or evil.

The peoples of ancient times could not attribute to their gods the vast control of the forces of nature which now lies in the hands of engineers and scientists. We have made great advances in scientific knowledge, but have we made an equal advance in the wisdom required to use that knowledge in the best interests of humanity? If we look at the present condition of the world, the answer must be an emphatic "No."

Although I would not declare a moratorium upon scientific research, I believe that the time has come when each one of us should pause and ask himself this question. "No matter how little my knowledge may be, have I the wisdom and the unselfish desire to use that knowledge in the best interests of humanity?"

It is not many years since all our engineering and scientific knowledge was concentrated upon the destruction of our fellow men. Today Europe is an armed camp in a state of potential warfare, and for all practical purposes New York is nearer to the seat of war than it was to Philadelphia a century ago.

I am not an alarmist, nor am I a pacifist, but I try to face the facts. There is little doubt that war will eventually come and when it does, it may wreck our civilization, and with it may go much of our engineering and scientific advancement because we have failed to prove ourselves worthy of our trust.

In the industrial field we have created a Frankenstein which we appear to be unable to control. We talk about overproduction, even of food, but why talk about overproduction of food when thousands have not enough to eat? In the most prosperous times there never was enough of anything to supply the reasonable needs of everybody.

Building is at a standstill, yet hundreds of thousands are living in quarters less suited to their needs than are the huts of the primitive savage.

Are we, who have been so largely responsible for creating these conditions, to ignore our responsibility and refuse to concentrate our efforts upon the task of finding a remedy for them? Shall we refuse to enter the field of economics, or any other field into which we may be led in our endeavor to find a remedy for the mistakes which our lack of wisdom has caused us to make?

Dr. Moss has quoted the parable of the wine makers and the bottle makers, but I would ask for consideration of a far older and better known story, the story of Solomon. Solomon was, perhaps, not a very good or moral man judged by our present-day standards, but he asked not for riches and power, but for wisdom to use rightly that which he had. Because of this his prayer was granted and other things also were added unto him, so that he has come down in history as a pattern for all men.

Have we followed the example of Solomon? Most decidedly we have not. No doubt we started out with the purest of motives in our search for scientific knowledge, but without any suspicion of the vast power, not only for good but for evil, which the gaining of that knowledge would place in our hands. The fault of the engineer has not been so much lack of appreciation of the good which our work might accomplish, but lack of recognition of the evil, and our moral responsibility with regard to it.

The charge has often been made that engineers as a class are too narrow in their interests. To some extent this is true, but I think that the many splendid papers and discussions by members of the A.S.M.E. which have recently been published afford clear evidence that engineers are taking a broader view of their responsibilities and obligations, not only as engineers but as citizens.

The need for a satisfactory readjustment of our highly technical civilization is so pressing and so vital that the advisability of focussing the attention of the technical press upon the intricate problems involved should be given careful consideration by all of us.

James O. G. Gibbons.[2]

"A Misleading Statement"

To the Editor:

In H. L. Seward's article "The Morro Castle Disaster" which appeared in Mechanical Engineering for January, 1935, there appears a misleading statement, as follows: "Staterooms were equipped with thermostatic detectors operating on any rapid rise in temperature, such as might be caused by a fire, no matter how small, in a confined space, with indicators on the bridge."

To one familiar with automatic fire-alarm systems, this sentence means that the fire detectors on the *Morro Castle* were of the "rate-of-rise" type, which do not require reaching a predetermined temperature for their operation, but rather operate when the rate of temperature rise exceeds a pre-set figure.

However, to our knowledge, the staterooms of the *Morro Castle* were equipped with spot thermostats having a fixed operating temperature.

Our reason for calling this to your attention is that we are the largest, if not the only, domestic concern which handles rate-of-rise fire detection for ships, and the article would infer that the *Morro Castle* was equipped with our service.

P. M. Farmer.[3]

[1] See page 124.

[2] Consulting Engineer, Bloomfield, N. J. Mem. A.S.M.E.

[3] Supervising Engineer, American District Telegraph Company, Inc., New York, N. Y.

Suggestion Systems

AT the 1934 Annual Meeting of The American Society of Mechanical Engineers two papers on suggestion systems for employees were presented and discussed. One of these papers, "Suggestion Systems," by Z. C. Dickinson, appeared in the November, 1934, issue of MECHANICAL ENGINEERING, and the other, "The Operation of a Suggestion System," by Virgil M. Palmer, was published in the December issue. Discussion on these papers commenced in the February issue, pages 122 and 123, and is continued as follows:

BY E. B. DITHRIDGE[4]

The papers by Professor Dickinson and Mr. Palmer have brought out the human-nature elements involved and the necessity of a sympathetic reception and handling of suggestions, as well as a sympathetic attitude toward the plan itself, all the way from gang foremen to the head of the business, if the management is to secure the potential tangible values of the plan. In a large, more or less complex organization, particularly when spread over a large territory, there is a reservoir of valuable suggestions, not necessarily brand new ideas, for which the attitude of foremen and officers will act either as a dam or a sluice.

As has been brought out, the foundation of any sound plan is a mutual spirit of cooperation, using the term in its broad sense with its numerous implications and responsibilities, and its values, intangible as well as tangible.

There is a "nuisance" side to the picture but with sympathetic attitude toward, and impartial and considerate handling of, suggestions, a year's experience will prove whether the nature of the business, and whether the rank and file organization is such that the tangible and intangible values make a continuance worth while. Many thoughtful employees—with valuable suggestions—will "hold back" for a time watching how the plan operates and whether it reacts undesirably against suggesters.

The notices posted to Pennsylvania Railroad employees invite any suggestion which any employee "believes will help improve our methods or operations, save time, effort, or material, expedite repair work or eliminate its necessity, or otherwise advance our mutual interests."

Some of the intangible values of a suggestion plan are:

It provides an inspiration to the intelligent use of latent powers of observation and analysis, encouraging, developing, and providing an outlet for constructive thinking, and satisfies an inherent desire for authorship of a useful idea.

It provides an outlet for self-expression for many who believe—and in some cases know from past experience—that their suggestions would not otherwise secure full and impartial consideration.

The plan's recognition on the part of the management of the capacity of the rank and file encourages and develops a spirit of cooperation, more careful thought, and observation in the performance of duty, use of materials and supplies, and methods of expediting work, and inspires greater and sustained interest in efficiency and progress.

The general knowledge that suggestions of the rank and file are being adopted by management develops mutual interest and esteem.

Explanations made concerning suggestions *not* adopted broaden thoughtful employees and undoubtedly increase respect for management where its methods, practices, or judgment were previously questioned by uninformed or misinformed employees. (This has no reference to wages, working conditions, or mere conveniences for employee alone, as any questions of that kind are handled by Pennsylvania Railroad employees through other provided channels.)

Furthermore, a suggestion plan probably spurs some of the supervision to closer observation and a more thoughtful analysis of traditional methods and practises, in order that they may not find their subordinates "beating them to it."

The question of confidential handling of suggestions, with no publicity, or of open handling with publicity as to adopted suggestions, is one which depends largely upon the nature of the business and its detail operations, i.e., whether the nature of the operations is such that there will be opportunity for thoughtful wide-awake employees to submit many suggestions on subjects or features which fundamentally are matters of intensive analytical supervision, or the nature of the business is such that suggestions will be largely confined to brand new ideas, such as new tools and designs.

The decision as to confidential handling will also depend to some extent on whether the management wishes to encourage observant and thoughtful employees (many of whom are modest and retiring with no desire for publicity), to submit suggestions on various methods and other details of operation which the employees feel might be improved upon to the advantage of the product, or the expense of operation or repair work.

Confidential handling will tap a reservoir of potential valuable suggestions which, in the absence of confidential handling, will never reach management.

The suggestion plan on the Pennsylvania Railroad is handled on the confidential basis, the name and occupation of the employee not being known to those to whom copies of the suggestion are forwarded for consideration. The posted notices promise confidential handling with a statement that in no case will a suggester's name be disclosed without first securing his consent. All contact with employees concerning their suggestions is by mail to the employee's residence address. Awards are paid in currency.

During the seven years the Pennsylvania Railroad's Bureau of New Ideas has been in operation, more than 12,000 suggestions have been received, *not* including more than 3400 suggestions which were more or less duplicates of ones previously received.

Of the 12,000 suggestions 3300 have been adopted either in whole or in part, or their consideration has brought about action to the advantage of the company in its operations, expenses, or service.

Suggestions have been received from 5400 different employees from every portion and department of the System, and representing 248 payroll occupation titles.

BY D. ARTHUR STRAIGHT[5]

Our own experience would cause me to amplify the thought expressed in the last paragraph of Professor Dickinson's paper, that if the supervisors are doing their jobs well, there is no real occasion for a suggestion system.

Excellent as such systems are, they should not be considered a panacea for all the benefits mentioned, particularly in the direction of the "morale" effect and better supervision. Suggestion systems should be adopted for the primary purpose of securing worth-while ideas, presupposing that the management has instituted other methods of obtaining better training, supervision, and "morale." The way to achieve better supervision is through organized foremanship-

[4] Bureau of New Ideas, The Pennsylvania Railroad, Philadelphia, Pa.

[5] Manager, Personnel Department, Henry L. Doherty & Company, New York, N. Y.

training; there are many methods of obtaining better employee "morale," among the less efficient being suggestion systems.

Our experience would lead also to the statement that the sponsors of a suggestion system, and those conducting it, must understand the workings of the company as a whole, must appreciate the relatively small part in it that the suggestion system plays, and must not offset its benefits by overzealousness or extravagant claims. To avoid some of the heartaches that arise in the use of suggestion systems, it is recommended that no special prizes be given for the "best" suggestion submitted; and that no campaign or contest for suggestions be held unless under very close supervision, because we have found that overzealous supervisors, ambitious for themselves and for the showing of their own sections, will try to force suggestions from their people when such ideas must perforce be spontaneous. The compulsion, the usually stale suggestions, and the disappointments are not conducive to better "morale."

BY H. M. HOOVER[6]

Our system parallels closely the system in use by The Eastman Kodak Company as described by Mr. Palmer, with the exception of the suggestion awards committee. I am led to believe on the basis of our efforts with committees on awards that committees soon fall into habits of dealing more or less perfunctorily with routines and that the success of a suggestion system, like a business, is the length and shadow of an enthusiastic individual.

Objectively, our system has been operating with a view to securing the ideas which naturally flow through the minds of our employees, to help clarify them, and thus get them into the open where they can be used.

I am strongly of the opinion that the foreman who contacts the employees more intimately than any one else in the organization should be part and parcel of the system and should be "sold" to the point where he becomes an enthusiastic booster for the ideas of those under his supervision, letting them know that he knows they have brains and inspiring them to use them for the mutual interests of themselves and the organization of which they are a part.

In furtherance of this objective in our system the foreman is kept fully informed about the initiation and progress of any suggestions submitted by any one under his supervision or any suggestion affecting his department by means of three forms.

Form A gives him the clock number and name of the suggester and also the subject matter of the suggestion.

Form B tells him that the investigator reports favorably, and requests his opinion of the fairness of the proposed award.

Form C informs him that the suggestion in the opinion of the investigator is without merit and should not be accepted. The reasons for rejection are set forth. He is requested to contact the maker of the suggestion and explain in detail why the idea was unacceptable. If the suggester is dissatisfied with the reasons for rejection this is reported on a detachable portion of form C which is returned to the suggestion chairman, providing the basis for further investigation.

BY JOHN D. HARNDEN[7]

Professor Dickinson speaks of many vitally important factors found in the operation of all suggestion systems. I will endeavor to comment briefly on these, speaking from long personal exprience with a suggestion system in a large plant of the General Electric Company.

Most of the available evidence from long-time successful systems indicates the desirability of a system for the rank and file of factory workers as a group, the dividing line being with the rank of foreman, with a separate system for rewarding employees in the supervisory group for outstanding contributions beyond anything expected in the course of normal duties. Greatest benefits accrue in these special cases when the manager personally makes the award and expresses encouragement and appreciation.

Wages, problems relating to working hours, rights of organization, and adverse criticism of tools are not the kind of matters to be handled through a suggestion system. Constructive ideas relating to the improvement of quality, reduction of cost of manufactured products, or betterment of any phase of routine or processes in the conduct of the business more properly fall within the scope of a suggestion system. The slogan "There is always a better way," expresses the opportunities open to employees, since most every element in the conduct of a business is susceptible to improvement.

It is of the utmost importance that the personnel of the committee be composed of men close to the management. Decisions must always be made by men most competent to do it to avoid the likelihood of their judgment's being questioned, and all transactions must be so handled as to inspire continuous confidence in the system through just and fair dealings.

We have found cash awards preferable, and the amount in each case must be sufficient to insure a satisfied suggester, i.e., payment made for all adopted suggestions with a minimum of $5 and no top limit. Personal contact by a member of the committee during the investigation and in the presentation of the award is an important point as a means of sensing employee reaction. Prompt making of awards, when suggestions are adopted, with a review after six months or a year in use, appears preferable to a plan of deferred awards.

Employees must have a personal feeling, through their contacts with those handling their suggestions, that their employer, after all, appreciates having received their suggestions. To accomplish this prompt action is essential, collections must be made frequently and investigated thoroughly, and a final decision must be rendered in the shortest possible time.

Many systems fail as a result of dissatisfied employees when their ideas are turned down. This is a major responsibility of the committee and the management, and the personnel of the committee must be able through personal contact and interview to convince each man that no injustice has been done. Unfavorable reaction from this part of the work could not be permitted to continue.

Professor Dickinson is correct in his conclusions that a relatively small number are in the class of inventions. Generally these come from the technical group, but nevertheless there exists in almost any business a broad and fertile field for the factory workers to make much use of their talents.

The point of view held by many is that if supervision is of a sufficiently high order, a suggestion system is not needed. I do not share this view, since industry has not as yet developed in large numbers supervisors sufficiently versatile and capable of covering the ground in a large modern manufacturing plant. Generally the most suggestions come from sections where the supervision is considered the best.

It is quite impossible for any one to evaluate accurately the relative benefits to the company and employees. It is a safe assumption, however, that no system could be successful where the desire of the management is all in the direction of obtaining the utmost in monetary

[6] Suggestions Chairman, Armstrong Cork Company, Lancaster, Pa.

[7] Assistant to Manager, Chairman Suggestion System, General Electric Company, Schenectady, N. Y.

benefits and giving as little as possible in awards to employees.

Benefits are of three kinds:

(1) Good-will between management and employees. This objective should be the guiding principle, with the constant thought in mind that it is a mutual undertaking for the benefit of both employees and the company.

(2) Those having value in money savings.

(3) Improvements in quality, in methods and processes, or ways of doing things where tangible savings are difficult of computation, but where good judgment clearly dictates their adoption.

"Foreman resistance" is mentioned frequently whenever suggestion systems are discussed. Obviously it is a major responsibility of the management to back the suggestion committee in getting the entire personnel of the supervisory force "sold" on the idea, even to the point where supervisors encourage the use of the system. The degree of success or failure achieved in various places in operating suggestion systems is in general a fair index of the relationship between management and men.

BY H. M. COOK[8]

Mr. Palmer's paper describing the suggestion system of the Eastman plant covers a comprehensive and, to my mind, an ideal suggestion plan. This plan has gone through the crucible of experience and has evolved through long years of trial, test, and experimentation.

The Brooklyn Edison Company's suggestion system has been in continuous operation since the latter days of the "mauve" period. Our present system is, in a great many respects, quite similar to the one described by Mr. Palmer. There are, however, a few points of difference which may be of interest.

Our suggestion committee consists of sixteen members, a chairman, a vice-chairman, a secretary, and a representative from each of the departments of the company—the representative from the personnel department being the safety engineer of the company. The secretary's entire time is occupied with suggestion work.

Suggestions are prepared and sent to the heads of the departments concerned by the secretary. Each week each member of the committee, or departmental representative, as he is called, receives a list of all the abstracted suggestions sent to the departments during the week. In addition to their duties as committee members—passing upon and discussing the suggestion, the amount of the award at the monthly meetings—the departmental representatives function as liaison agents between the suggestion committee and the suggester, and the suggestion committee and the department head. They are also the new business agents for suggestions in their departments. The departmental representative advises the suggester regarding his suggestion, supplements by personal interview the secretary's explanation of why a suggestion was turned down, and clears up any doubts or uncertainties in the suggester's mind. The departmental representative keeps the department head informed on all suggestion matters and follows the progress of all suggestions sent to his department.

The advantage of this arrangement in our organization is convenience. Parts of our organization are widely scattered. The departmental representative is a person whose duties require him to meet the people in his department. He, consequently, is in a position readily to meet all suggesters in his department. We believe that the institution of the departmental representative has been a great step forward and makes possible the efficient and expeditious handling of a large number of suggestions.

At the monthly meetings, we are now disposing of from 150 to 225 suggestions in a period of from two to two and one-quarter hours. This is accomplished by preparing as fully as possible before the meeting, the disposition of the suggestion and the amount of award. Where differences of opinion exist, the secretary confers with the departmental representatives concerned and secures, if possible, an agreement. In the few cases in which agreement cannot be obtained before the meeting, the matter is thrown before the entire committee. In the great majority of cases, however, it is possible to take one vote on the rejection of a group of suggestions or one vote on the acceptance of a group of suggestions with a $5 award.

Certain points which we are considering at present and about which we should like to secure advice are as follows:

(1) Attitude on eligibility and standards of eligibility.

(2) Whether the whole amount of award shall be given immediately or whether a nominal prize shall be given at the time of acceptance, with consideration later for additional yearly prizes.

(3) Whether suggestions similar to the one already accepted but applying to different locations shall also be accepted.

(4) In case of several suggestions covering the same idea, which have been rejected, and a change of conditions makes it desirable to accept later, which one or ones shall be given an award.

[8] Assistant Director, Personnel, Brooklyn Edison Co., Brooklyn, N. Y.

A.S.M.E. BOILER CODE

Interpretations

THE Boiler Code Committee meets monthly for the purpose of considering communications relative to the Boiler Code. Any one desiring information on the application of the Code is requested to communicate with the Secretary of the Committee, 29 West 39th St., New York, N. Y.

The procedure of the Committee in handling the cases is as follows: All inquiries must be in written form before they are accepted for consideration. Copies are sent by the Secretary of the Committee to all of the members of the Committee. The interpretation, in the form of a reply, is then prepared by the Committee and passed upon at a regular meeting of the Committee. This interpretation is later submitted to the Council of The American Society of Mechanical Engineers for approval, after which it is issued to the inquirer and published in MECHANICAL ENGINEERING.

Following are records of the interpretations of this Committee formulated at the meeting of January 4, 1935, and approved by the Council.

CASE No. 789

(*Interpretation of Par. P-325*)

Inquiry: Is it permissible, under the provisions of Par. P-325 of the Code, to attach supporting lugs for boilers by welding instead of riveting?

Reply: It is the opinion of the Committee that provisions should be made for attachment of the supporting lugs, hangers, or brackets of boilers by fusion welding and that the intent of the Code will be met provided (a) the lugs, hangers, or brackets are made of steel plate sanctioned by the Code for use in the shells of boilers; (b) they are of the same size as

required for riveting; (c) they are attached by fillet welds along the entire periphery or contact edges of the size and form shown in sketches 1 to 4, inclusive, in Fig. P-7, in which t_n is the shell thickness; (d) the welding meets the requirements of Pars. P-101 to P-111, inclusive, omitting the radiographic examination; (e) the supporting lugs, hangers, or brackets are attached prior to stress relieving; and (f) the stresses, computed by dividing the total load on the lug, hanger, or bracket by the minimum cross-sectional area of the weld, do not exceed, for tension and compression 40 per cent, and for shear 32 per cent of the stress values given in Table P-8 multiplied by the welded-joint efficiency.

CASE No. 797

(Annulled)

CASE No. 798

(In the hands of the Committee)

CASE No. 799

(Interpretation of Pars. P-15 and P-16)

Inquiry: Case No. 769 permits the use of chrome-manganese-silicon boiler plate (Specifications S-28) for riveted-drum construction. Par. P-15 limits the crushing strength of steel plates to 95,000 lb per sq in., and Par. P-16 gives the ultimate strength in single shear for steel rivets as 44,000 lb per sq in., and 88,000 lb per sq in. in double shear. May these values be increased for the chrome-manganese-silicon steel plate (Specifications S-28), and what corresponding values should be used in designing riveted drums built from such material?

Reply: The crushing strength for plate in accordance with Specifications S-28 for the Grade A material, which is the only one that will be used for rivets, should be limited to 120,000 lb per sq in. The ultimate strength for rivets in single shear is 60,000 lb per sq in., and in double shear 120,000 lb per sq in.

CASE No. 800

(Interpretation of Par. UA-22d)

Inquiry: Par. UA-22*d*(1) requires a flange hub height which is excessive for shells or pipes having heavy walls. Would not some shorter height of hub be sufficient in the case of flanges attached to shells or pipes 1 in. or greater in thickness?

Reply: It is the opinion of the Committee that the intent of this rule will be met if a minimum distance of 3 in., measured from the back of the flange, is used for the height of the hub with vessels or pipes 1 in. or greater in thickness. The straight section of the hub as required in Par. UA-22*d*(2) should be at least $1\frac{1}{2}$ in. in such cases.

CASE No. 801

(Interpretation of Par. P-102e)

Inquiry: If the joint tension test specimen under Par. P-102*e* fails outside the weld within the base metal and the tensile strength is less than the minimum of the specified tensile range of the plate used, does this constitute a cause for rejection of the plate?

Reply: The acceptance of the plate is based on the tests required in the plate specifications. It is recognized that stress relieving may reduce the tensile strength of the plate as received from the mill but this reduction in tensile strength is considered to be covered by the factor of safety of 5. The tension test on the joint specimen specified in Par. P-102*e* is intended as a test of the welded joint and not of the plate.

REVIEWS OF BOOKS

And Notes on Books Received in the Engineering Societies Library

Industrial Profits

INDUSTRIAL PROFITS IN THE UNITED STATES. By Ralph C. Epstein, National Bureau of Economics Research, New York, N. Y., 1934. Cloth, 6 × 9 in., 678 pp., 123 tables, 69 charts, $5.

REVIEWED BY E. DILLON SMITH[1]

THIS book is a cooperative effort of the Committee on Recent Economic Changes and the National Bureau of Economic Research. It is directed to the dynamic economic factor of profits, the variation of which dominates the direction and extent of business enterprise.

The principal questions that this book seeks to answer are: What rates of profit do large and small corporations earn upon their capital investments in the various branches of manufacture, trade, finance, and mining? What is the range of the rates of profit? How do the rates fluctuate from year to year? Are the rates in the several industries equal? Do rates of return vary with shifts in general business? Are the larger corporations more profitable than the smaller? Do the different industries return different rates of profit and do they maintain their relative positions over a period of time?

Dr. Wesley C. Mitchell, professor of economics at Columbia University, has discussed the problem of measuring profits as a preliminary note to this volume (No. 26). After this note Dr. Epstein, professor of economics at the University of Buffalo, has presented his able essay.

Business profits are among the hardest kinds of income to measure, and much effort has been directed toward this end. This present effort seems to be of unusual merit due both to its thoroughness and to its conclusions that tend to upset some of the orthodox economic theories. Actually, profits are known only when a corporation or business is terminated or liquidated. Estimates of profits are all that can be made for any going concern, the task of which is exceedingly difficult as the size of the business increases and the inaccuracies of income statements are realized. Another difficulty in measuring profits is the variation in time of what constitutes profit in the variable income streams. Suffice it to say that little has been overlooked in the handling of the complex problems connected with the estimation of industrial profits.

This volume is divided into four books: I, the broad findings; II, earnings of large corporations; III, earnings of small corporations; and IV, problems of estimation and interpretation. These are followed by four appendixes.

[1] University Fellow, Columbia University, New York, N. Y.

Some of the findings of this volume can be presented in their broad aspects as follows: The major sample includes 3144 enterprises of which 2046 are for manufacturing, 664 are for trading, 346 for finance, and 88 for mining. The record for this group is unbroken for the years 1919–1928. Supplementary statements for 71 enterprises carry the record through 1932, which is a representative sample of the major sample. The validity of any inference that has been drawn from this major sample has been substantiated by a comparison with about 340,000 enterprises drawn from the "Statistics of Income" of the Bureau of Internal Revenue. Although this major sample comprises but a small fraction of the total number of enterprises in this country, their "capitalization comprises approximately one-third of the entire corporate investment in the four broad industrial divisions that they represent."

The returns on capitalization for the combined major sample of 3144 enterprises extending over the continuous period of 1919–1928, aggregated 10.5 per cent. The returns for the four industrial divisions are: manufacturing, 10.8; trade, 13.6; finance, 10.7; and mining, 4.9. In the manufacturing division it was found that the upper quartile earned profits of 18 per cent or more.

This major sample of enterprises comprises 106 industries. The aggregated rates of return for each industry show a wide diversity. Those at the bottom of the list are meat packing, castings and forgings, and rubber products, with a return of less than 6 per cent on their capitalization. Some of the industries that earn more than 25 per cent are scientific instruments, newspapers, and toilet preparations. The lowest quartile of industries earns under 10.6, the highest above 15.4, while the median or middle rate of return is 12.6 per cent. It then follows, and it is shown, that there is a permanence of profit differentials in time. The usual economic concept that profits tend to an equality is suggested as being in error. In other words, those "industries in which earnings exceed the median return by the largest relative amounts in any one year lose no significant part of their high relative earning power over a six-, eight- or even ten-year period. Indeed, except for such temporary changes in average levels of earnings as accompany a year of marked depression, they retain a rather constant measure of advantage."

Since the business world attaches considerable importance to the relation between net earnings and sales, this operating ratio has been studied. In the manufacturing division the rate of capital turnover, as a whole, is about 1.2. In trading it is 2.7.

The five industries earning about 20 per cent or more upon sales are, in order, scientific instruments, textile machinery, portland cement, general factory machinery, and proprietary preparations. On the other hand the lowest group is meat packing, flour milling, rubber products, dairying, and miscellaneous leather products. In trading the best returns on sales are from jewelry, lumber and coal, and building material; while the best returns on investment are automobiles, groceries, and men's clothing in the order mentioned.

Rather conclusive results were obtained in showing that by far the highest rate is earned by the smaller corporations, i.e., those with an investment of less than $500,000. There also seems to be certain geographical advantages for some industries.

The matter of cyclical fluctuations in profits is considered at great length. It is shown that 1926 was more profitable than 1928 or 1929. There is also suggested that the profit situation in 1925–1926 was essentially the same as that in 1928–1929, and that the cause of the industrial collapse cannot be fully placed at the hands of the entrepreneurs. The discussion on cycles is of considerable moment, even though it is incomplete. All of these subjects, and others, are discussed in minute detail by Dr. Epstein.

The subject of industrial profits has been discussed in an able manner. The major theme is most informative and offers much to the industrialist.

Swiss Machinery Industry

"VEREIN SCHWEIZERISCHER MASCHINEN-INDUSTRIELLER—1883–1933." Prepared for the V.S.M. by Dr. B. Lincke, Effinghof A. G., Brugg, Switzerland. Paper, 8¼ × 11¾ in., 93 pp., illustrated.

REVIEWED BY LEON CAMMEN

ON THE occasion of the fiftieth anniversary of the Swiss Association of Machinery Manufacturers (V.S.M.) Dr. Lincke prepared a survey of the history of the Association during this eventful half century and also a review of the development of the Swiss machinery industry. This includes a review of the tariff and commercial history and policies of the Federal Swiss Government.

The author says that nowhere is there a greater contradiction between theory and practice than in the trade policies of the nations. All theory supports free trade and yet there is a clear tendency toward economic autarchy or national self-sufficiency. This is said to apply particularly to the case of Switzerland. Its natural location is such that home production cannot satisfy its requirements even with a reduced standard of living and a smaller population. For a long time there was a pressure toward commercial expansion; and in the older days, when exchange of goods was restricted, this tendency resulted in Swiss citizens entering the foreign military service. The situation has since changed, but economic self-sufficiency cannot become a national Swiss policy. To export goods and to buy foreign raw materials a system is necessary which is contradictory in its fundamentals; and the representative of the association points out that any artificial manipulation of prices makes the body politic permanently inflexible. He believes, therefore, that state and municipal control in the field of economics must be reduced to a minimum even in times of crises.

The chapter devoted to the War and post-war periods tells how Switzerland, located between the belligerents and under various forms of control, carried on until the armistice, and how, thereafter, first foreign restrictions and then domestic regulation have been gradually loosened. The chapter on the social policy of Switzerland includes a table of wages for adult workers at the beginning of 1933. Taking the wages of skilled Swiss workmen as 100 per cent, similar wages in the Netherlands were nearest this figure, being 97 per cent, while Czechoslovakia and Hungary were at the bottom of the list with 54 and 43 per cent. Figures for the United States are not included. Up to the time of the War the hours of work were very long indeed, a maximum of 11 hr per day being allowed by the Federal legislation of 1877. During the War the 54-hr week came into existence, followed soon after by the reduction first to 50 hr and later to 48 hr. These changes are frankly ascribed to the pressure of the powerful social awakening which swept the world upon the signing of peace. It was soon found, however, that a rigid restriction of working hours to 48 per week without proper provision for overtime constituted too narrow a regulation, especially in view of the competitive character of international trade.

A revision of the appropriate provisions of factory legislation offered the necessary changes, but when it came to a referendum in February, 1924, the new law was rejected, and the machine industry had to rely on the granting special exceptions in individual cases of particu-

lar urgency in order to operate on a 52-hr week. Later because of the negative attitude of the Federal authorities, even this path toward longer hours seems to have been closed.

Brief references are made to social insurance and welfare provisions, whereupon the author proceeds to a discussion of limits of social policies and the position of wages as a factor in the determination of costs and markets for various goods. The author does not agree with the theory that the purchasing power of the masses can be greatly increased by a rise in wages. He points out that wages constitute only a part of the total national income and that other cost factors in production, such as interest on capital, taxes, cost of transportation, and profits, affect purchasing power in so far as the employer is concerned in the same manner that wages affect the purchasing power of employees. He comes to the conclusion, therefore, that increases in wages produce a *shift* in purchasing power rather than an *increase* of it. Even in times of booms rises in wages must be held within proper limits as otherwise they may do harm to the very workmen who receive them. Only too often have people considered every rise in wages as evidence of social-political progress.

Dr. Lincke believes that a little less "social mindedness" might be more in the interest of the working population. On the other hand, he is strongly in favor of rationalization of industries and believes that no sound economic system, and particularly no system depending on export for its welfare, can do without the application of the principle of rationalization, including the absorption of labor released from one group of industries into some other field of production process. He believes that when proper methods of rationalization have been applied it is not at all necessary that there should be prolonged periods of unemployment. He insists, however, that the main point in all economic systems is the increase in production, while the importance of the distribution of goods has usually been given far too much consideration. As a result of this he does not believe in a 40-hr week and claims that such a measure would merely consolidate lower production values and constitute a resistance to the raising of the standard of living.

Such important subjects as the promotion of exports, patent law, and transportation are rapidly surveyed. There follows a brief history of the development of industries in Switzerland, showing, for example, that the number of factory employees in the machine and metallurgical industries, which does not include watch-making, rose from 20,000 in 1888 to 114,000 in 1929, while the power used in that industry increased from 8000 hp in 1888 to 180,000 hp in 1929, and that this class of industries has assumed a far more important position in the general industrial system than was the case fifty years ago.

In Switzerland, as elsewhere, the recent years have been characterized by the production of larger units and application of higher temperatures, pressures, and velocities. Increased importance has been attained in Switzerland by the production of rolling stock for main and secondary railroads, mining, and tramway transportation, while, because of extensive distribution of electricity and increase in consumption of that kind of energy, important progress has been made in the field of electric meters and in measuring apparatus generally.

The last chapter is devoted to a consideration of general economic policies. In this connection the author considers the existence of two systems of price inflation—one due to native credit expansion, and the other to the international relationships of creditor and debtor which grew up as a result of the War. This latter seems to have completely collapsed and in place of promotion of credit we now find credit restrictions.

A table is given showing average exports. From this it would appear that the reduction of exports between 1929 and 1933 was 72 per cent in the United States, 67 per cent in Holland, 64 in France and Italy, 61 in Germany, 60 in Switzerland, and 54 in England.

Systems of economic planning and current attacks on the capitalistic system are briefly presented.

In conclusion the author states that the path of the industry toward a brighter future lies not along the lines of restriction and compulsion, but exclusively along those of the free development of natural forces—not in self-sufficiency but in world-wide cooperation.

Books Received in Library

AERODYNAMIK. Vol. 1, Mechanik des Flugzeugs. By R. Fuchs, L. Hopf, and F. Seewald. Second edition. Julius Springer, Berlin, 1934. Cloth, 6 × 9 in., 339 pp., diagrams, charts, tables, 30 rm. Progress since the first edition of the author's treatise on aerodynamics has made it necessary to expand the work beyond the dimensions of one volume. The present book, the first section of this new edition, considers the mechanics of aircraft. It discusses comprehensively the problems of equilibrium and stability, developing the formulas involved and giving a large number of numerical values for them, as developed in practice and experimentation.

A.S.T.M. STANDARDS ON ELECTRICAL INSULATING MATERIALS, prepared by Committee D-9 on Electrical Insulating Materials. American Society for Testing Materials, Philadelphia, October, 1934. Paper, 6 × 9 in., 281 pp., illus., diagrams, charts, tables, $1.75. This volume brings together all the specifications and test methods for electrical insulating materials which the Society has adopted, in their latest approved form. In addition it contains the latest report of the committee in charge of this subject, discussing the developments of interest during the past year.

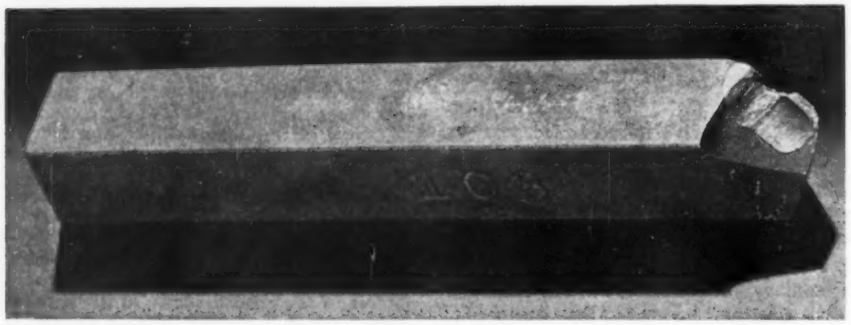
FROM GALILEO TO COSMIC RAYS, a New Look at Physics. By H. B. Lemon. University of Chicago Press, Chicago, 1934. Cloth, 7 × 9 in., 450 pp., illus., diagrams, charts, tables, $5. This is a textbook of physics, intended for use in the general course in the physical sciences required of undergraduate students at the University of Chicago. It is designed to be read from cover to cover within a reasonable time, to stress the source material and phenomena, and to interpret them in nontechnical style and by homely analogy. The book has none of the characteristics of the usual textbook, yet it provides an admirable course in physics which will appeal to adult readers in search of a modern, readable account of the subject.

GREAT BRITAIN, Department of Scientific and Industrial Research. REPORT OF THE FOOD INVESTIGATION BOARD FOR 1933. His Majesty's Stationery Office, London, 1934. Paper, 6 × 10 in., 248 pp., diagrams, charts, tables, $1.20 (British Library of Information, New York). This report describes the research work carried on during the year at the research stations and laboratories directed by the Board. This included investigations of the preservation of meat, fruit, and vegetables by refrigeration, the effect of atmospheres of various compositions upon fruits, and extensive investigations of gas storage for foods. Various researches in heat transmission, insulation, etc., were also conducted.

JON JACOB BERZELIUS, Autobiographical Notes published by the Royal Swedish Academy of Sciences through H. G. Söderbaum; translated from the Swedish by O. Larsell. Williams & Wilkins Co., Baltimore, 1934. Cloth, 6 × 8 in., 194 pp., illus., $2.50. This autobiography was prepared for the archives of the Swedish Academy of Sciences and covers the author's life to 1840, eight years before his death. It is a human document, describing his youthful struggles for an education, his travels, and his relations with fellow workers. The translation is excellent.

SHIP DESIGN, RESISTANCE AND SCREW PROPULSION. Vol. 2, Marine Screw Propeller and Propulsion of Ships. By G. S. Baker. Journal of Commerce and Shipping Telegraph, Liverpool; Charles Birchall & Sons, Ltd., London, 1933. Cloth, 7 × 10 in., 176 pp., diagrams, charts, tables, £1, 5s. In the present volume of this work, the superintendent of the William Froude Laboratory discusses the conditions of ship propulsion, the theory of screw action, model screw-propeller experiment, propellers in open water, single-screw ships, twin screws behind ships, multiple screws, shallow-draft steamers, cavitation and propeller failures, and steam trials and log analysis. The book will be welcomed by all designers.

WHAT'S GOING ON



SHOWING TYPE OF FAILURE OF CUTTING EDGE OF A LATHE TOOL USED IN SOME EXPERIMENTS CONDUCTED BY THE A.S.M.E. COMMITTEE ON METAL-CUTTING DATA

Handbook of Metal Cutting Proposed

A SUBCOMMITTEE on Metal Cutting Data, organized by the A.S.M.E. Special Research Committee on the Cutting of Metals, has prepared a progress report on its activities and program. Robert Corey Deale is the executive secretary of the subcommittee. The report follows:

For some time it has been apparent to the Special Research Committee on the Cutting of Metals that there is a great need for an authoritative publication of data on the cutting of metals, in a form readily available for, and easily usable by, the production executive. Frederick W. Taylor presented "On the Art of Cutting Metals" in 1906 as his contribution toward the shifting of this important branch of manufacturing technique from an empirical to a sound engineering basis. Taylor presented this paper not as a completed and perfect investigation of the subject, but as a means of indicating the direction in which additional work was indicated and the best methods for carrying on such work. It is believed that he would be greatly disappointed in the relatively small amount of information that has been added to the subject since he completed his experimental work. Much valuable experimental work has indeed been carried on in the past thirty years, but little has been done to correlate this work and to put it in a form convenient for shop use, particularly in this country. A start in this direction has been made in Germany through the publication of a series of data sheets by the Ausschuss für Wirtschaftliche Fertigung, and in England through the work of the Lathe Tools Committee of the Manchester Association of Engineers. The data from these sources, while much more suitable for shop use than anything now available in the United States, are by no means as complete as it is thought to be desirable for use in this country.

The Subcommittee on Metal Cutting Data was formed by the A.S.M.E. two years ago to study all available experimental data, to arrange for and conduct such experimental work as was found to be necessary to supplement existing data, to correlate these data into a form convenient for shop use, and to publish them in a form convenient for shop use. A preliminary study has indicated that publication will probably be in the form of a number of handbooks, approximately as follows:

(1) General and single-pointed paring tools, such as are used for rough and finish machining on lathes and planers.

(2) Drilling, tapping, threading, and reaming tools.

(3) Milling operations.

(4) Miscellaneous tools, including those for gear cutting, thread cutting, thread milling, broaching, sawing, and profiling.

At present no decision has been made as to whether this committee should eventually undertake a study of the operations performed with abrasives, such as grinding, lapping, honing, and polishing.

Many of the data necessary for the first handbook of the series have already been collected and are now being worked into shape for publication which, it is hoped, may take place at an early date. Careful study of these data has indicated that, while it will be possible to cover some sections of the field with considerable precision, others must, for the present, be covered much less thoroughly because of the small amount of accurate information available. For this reason it is realized that the first publication must be in the nature of a first approximation, although it is believed that it is possible to put out a source of information so much more helpful than anything now available that it should be presented as soon as possible.

It is believed that one function of this committee will be to correlate all the experimental work being carried on in this country, so that it may tend to form part of a well-rounded program, rather than a mass of disconnected data, at times duplicating data already available, or possibly obtaining results for which there is no immediate need.

To determine the relative importance of the various tool materials, a questionnaire was sent out at the beginning of this study to a group of companies so selected as to cover all branches of the machining industries. The returns from these questionnaires indicated that at the time not more than 5 per cent of the machining of the country was being carried on with stellite and carbide tools. While this percentage will undoubtedly increase, it was decided that, for the present, work should be concentrated on cutting with high-speed-steel tools. Later, when carbide tools have passed the present developmental stage and are used in appreciably greater quantities, it may be desirable to carry on the work for such tools.

The first handbook will contain data on tool material, heat treatment, tool grinding, effect of tool shape and chip proportions, effect of cutting speed on tool life, tool strength, chip pressure, horsepower, chatter, effect of the ratio of unsupported length of work to work diameter on the rate of metal removal, coolants, economic tool life, most economical feed, chromium plating of tools, nitriding and case-hardening of tools, relative machinability of materials used in machine-shop practice, methods of running cutting tests, and tables of cutting speeds and horsepower.

While the work of the subcommittee has been much handicapped by the lack of adequate financial support, it is believed that it will be possible to produce the first handbook of the series with support now available from the Engineering Foundation. It is believed that the data in hand, while less complete than might be desired, can be put out in a form which will cover with an entirely satisfactory degree of accuracy much of the work performed with the single paring tools used on lathes and planers. Such a volume, compiling in usable form the best of the available data, should be of very great practical value. It is hoped that its publication will indicate to industry the practical value of the work which the committee has undertaken, and will facilitate the raising of the funds necessary to complete its full program.

Young Engineers to Uncover New Opportunities

A COMMITTEE of young engineers of the Junior Group of the Metropolitan Section of The American Society of Mechanical Engineers plans to investigate the more important units of the consumers-goods industries. The purpose of this study is to search for actual or potential opportunities for the engineer in this field. The findings will be

made available to the engineers and the industries to their mutual advantage, so that the engineer may increase the scope of his activities and the industries can benefit by the application of engineering technique.

The following data will be sought in the investigation of each field: The volume of business, its capital investments, the number and type of employees, the kind of service or product sold, the type, cost, and probable life of the machinery it uses, the size of its plants, the business changes affecting it and their probable causes, the ratio of engineers to labor and engineering salaries to wages in the field, trends in development, and the kinds of work, technical, semi-technical, and non-technical that are offered.

TWO SUBCOMMITTEES WILL MAKE STUDIES

In order to collect as many pertinent data as is possible in the allotted time, the committee has been divided into two sections so that two approaches may be carried on more or less simultaneously. The first subdivision proposes to collect its data by personal contact with the leaders of the industries under study. These contact men will endeavor to obtain a description of the industry; and wherever possible will supplement the descriptions with actual observations of the plants and processes. They will view the industries not only in relation to the effectiveness of the success or failure of the past applications of the engineering technique but will endeavor to discover processes that might possibly be facilitated or performed more easily by the application of engineering principles.

While the contact men are getting a picture of the industries from actual observation of individual plants, the second group will collect data by a study of each industry as a whole. The description will be derived from data from government publications, trade journals, trade associations, chambers of commerce, and the other available sources.

The procedure outlined is to be used as a guide to uncover more methods of attacking the problem. The present objective is to obtain a picture of the industries. The investigation may uncover facts that may change the procedure and even vary the objective. The groups will interview some of the young engineers in the industries for the purpose of obtaining their points of view.

When a comprehensive picture of an industry has been made, both groups will review the evaluation of the industry in the light of the facts and will endeavor to predict what opportunities lie in the industries for engineers by the utilization of methods that are now established in the industry. The committee will also endeavor to discover what methods might be susceptible to the engineering technique used in allied fields, such as time study, materials handling, inspection, and testing, and also what new methods could be introduced by engineers to aid the industry.

The committee of the Metropolitan Junior Group is known as the Committee for the Investigation of New Industrial Fields. Eugene Koenig is chairman, and the chairmen of the subcommittees are Joseph Nelson and William J. McLarney.

American Engineering Council News

A MOVE toward better coordination of engineering organizations throughout the country was the main outcome of the annual meeting of American Engineering Council, January 10 to 12. Public-affairs committees to be set up in each state will insure a closer tie-in of local societies and sections toward joint action, will give the Council established agencies with which to deal on a state-wide rather than on a local basis, and will fill a gap in the present system of engineering organization.

Highlights of the meeting include a symposium of Federal work by prominent Washington officials; evidence of increased interest of national societies in the work of Council, and a concurrent meeting of the secretaries of engineering societies. Engineering groups in 41 states were represented. Another assembly is scheduled for October, bringing in boards of control of national societies.

NEW MEMBERSHIP PLAN

A flat rate of nominal dues for local societies with delegates of A.E.C. meetings arranging their own expenses; with division of the country into nine districts so that a group of societies in each may send a joint delegate with expenses paid by Council is the essence of the new membership plan. Individual societies under a joint membership plan, however, may send delegates at their own expense.

Adoption of the new membership plan automatically brought into the Council the Engineers Club of Philadelphia and the Engineering Societies of New England. At least a dozen others have indicated their intention of joining. For information, inquiry should be addressed to the American Engineering Council, 744 Jackson Place, Washington, D. C.

PUBLIC AFFAIRS

A public-affairs committee will be set up in each state, and will be made up of key men from local societies and sections. This plan does not contemplate the creation of state councils but rather the setting up of central groups to represent engineers throughout the state in public matters of moment to the profession and to cooperate with national activities of Council. The present Public Affairs Committee of A.E.C. is to be divided into subcommittees with interlocking membership in similar bodies of the engineering societies toward unified action.

CONFERENCE OF SECRETARIES

The secretaries of some forty national, state, and local engineering societies met for the first general conference since 1929. Earlier conferences ran biennially from 1923 until that date. C. E. Sabin, secretary of the Cleveland Engineering Society, presided. Another meeting is tentatively set for Pittsburgh in June, 1936, under the chairmanship of K. E. Treschow, secretary, Engineers Society of Western Pennsylvania. Meanwhile, a Committee on Coordination of Engineering Organizations, headed by O. L. Angevine, secretary, Rochester Engineering Society, will study overlapping dues and related problems.

An exchange of successful experience as to society management was the main purpose of the Secretaries' Conference. George T. Seabury, secretary, Am.Soc.C.E., led the discussion on relief activities which brought out the varied action of societies in assembling private funds or securing public aid for work and relief projects for unemployed engineers. Handling dues for unemployed members, methods of collecting dues, and means of hold-

THE EXECUTIVE COMMITTEE OF THE AMERICAN ENGINEERING COUNCIL

(Standing, left to right: C. O. Bickelhaupt, vice-president; W. H. Woodbury, vice-president; and Col. Paul Doty, vice-president. Sitting, left to right: C. E. Stephens, treasurer; F. M. Feiker, executive secretary; J. F. Coleman, president; and A. J. Hammond, vice-president. Dr. Willliam McClellan, also a member of the Committee, was unable to be present.)

ing successful conventions and dinners were topics discussed.

WASHINGTON NEWS

The $4,880,000 works bill gives the President almost dictatorial powers over a vast employment program. Details are vague, but it seems safe to predict that almost every Federal activity requiring engineers is due for some further expansion. The proviso that the work be useful will require technical direction.

Engineers seeking employment must be reminded that nothing can happen until the bill passes and the new set-up begins to function. Meanwhile, little new employment is being offered by the government and some lay-offs are being made. It has not been revealed which agencies will handle the new work.

Survey and planning projects, offering a high ratio of engineering employment, have been given impetus by the report of the National Resources Board. The $117,000,000 mapping program to complete the map of the United States in ten years is believed to have a good chance of adoption. It would employ as many as 5000 engineers.

Questionnaires for the survey of the engineering profession, by the U. S. Bureau of Labor Statistics in cooperation with A.E.C., will begin to go out in the near future. Commissioner Lubin, in his talk before the Assembly of Council, laid repeated stress on the need for engineering societies to prod their members so that returns will be prompt and complete. Upward of 100,000 blanks will be mailed. The greater the return, the better the profession will be prepared to cope with its problems on a factual basis.

Actions of A.S.M.E. Executive Committee

AT ITS meeting of January 12, 1935, the Executive Committee of the Council of The American Society of Mechanical Engineers took the following actions of general interest:

LOSS OF SENIORITY

The committee voted to rescind certain previous actions relating to loss of seniority and to establish the policy by which the 128 individuals who accepted the loss of seniority plan in the policy of April 1, 1934, will appear in the printed records of the Society with their proper dates of election to various grades of membership. However, in calculating the number of years for which dues are paid as a basis for dues exemption according to B5 of the By-Laws, only the number of years for which dues are actually paid are to be considered.

MEMBERSHIP INCREASE

Appointment was authorized of a committee to develop plans to increase the membership with men of high grade.

LICENSING AND REGISTRATION

It was voted to express approval of a policy of encouraging officers of sections and members to aid the adoption of state licensing laws in accord with the model law approved by the Council in 1932.

APPOINTMENTS

Appointments voted and reported for record were as follows:

Representative on Advisory Council, National Society of Professional Engineers, Harold V. Coes.

Second alternate, A.S.M.E. delegation on the American Engineering Council, Harold V. Coes.

Council representatives on Finance Committee, Ely C. Hutchinson (one year, to fill unexpired term of W. L. Batt) and James H. Herron.

Professional Conduct, Hugo Diemer.

Education and Training for the Industries, Geo. A. Seyler (one year, to fill unexpired term of C. F. Bailey) and Philip E. Bliss.

Boiler Code Committee, Walter Samans and A J. Ely.

"Spirit of St. Louis" Medal Award, Victor J. Azbe, chairman, and C. B. Millikan.

National Management Council, Harold V. Coes.

Safety Code Correlating Committee, M. H. Christopherson and T. A. Walsh, alternate.

Standards Council, A.S.A., C. W. Spicer, and V. R. Willoughby and C. B. LePage, alternates.

Engineers' National Relief Fund, W. A. Shoudy (to fill vacancy caused by death of W. W. Macon).

Honorary chairmen of student branches; J. A. Trail, Agricultural and Mechanical College of Texas, and L. L. Vaughan, North Carolina State College.

General Committee, Sixth Annual Greater New York Safety Conference, H. H. Judson.

Engineering Conference, Melbourne, Australia, F. Ernest Stowe.

Apply for Freeman Scholarship Before May 15

APPLICATIONS for the John R. Freeman Traveling Scholarship must be filed on or before May 15, 1935, according to an announcement by the Committee on the Freeman Fund, A.S.M.E., composed of Charles T. Main, chairman, Ely C. Hutchinson, and Clarke Freeman.

The Freeman Fund was established by John R. Freeman, former president and honorary member of The American Society of Mechanical Engineers, and provides a traveling scholarship for the purpose of promoting in this country a greater interest in the work of European hydraulic laboratories and making the engineers in America more familiar with European practice in the design and construction of hydraulic works. The award will be made to the candidate who seems best equipped to learn European hydraulic practice and to disseminate such knowledge in this country.

CONDITIONS OF AWARD

To be eligible for this scholarship a candidate shall be an American citizen, not less than 24 years of age nor more than 35 years of age, who is a graduate of a technical school of recognized standing, or an instructor or an assistant in a technical school in which hydraulics is an important part of the curriculum. It is desirable that candidates for the scholarship be members in one or the other grades of The American Society of Mechanical Engineers.

A candidate shall be familiar with the mathematical treatment of hydraulic problems and well grounded in general mathematics. He shall preferably have had experience in hydraulic design and construction. A good grounding in the German language is considered essential and preference will be given to those candidates who can speak this language.

The sum of $100 per month has been made available for this scholarship, not to exceed 15 months. The candidate to whom the scholarship is awarded shall bear all other expenses, if any, for tuition, traveling, or other purposes. He shall leave this country to take up his studies in Europe on or immediately after July 1, 1935, and shall at once begin his work at one of the technical schools at which arrangements may be made for instruction in scientific hydraulics and the use of models for the solution of hydraulic problems. The studies will be largely confined to Germany and not one but many of the hydraulic laboratories of Europe shall be visited. One of the important features of the year's work will be visits to the more important hydraulic works in the vicinity of the school at which the course of study is being taken.

Brief progress reports addressed to the Secretary of The American Society of Mechanical Engineers must be submitted each month by the holder of the scholarship for the information of the Committee on Freeman Fund. At the conclusion of the year of study the holder of the scholarship shall submit to the Society in form suitable for publication a monograph on current hydraulic practice in Europe and the work of European hydraulic laboratories.

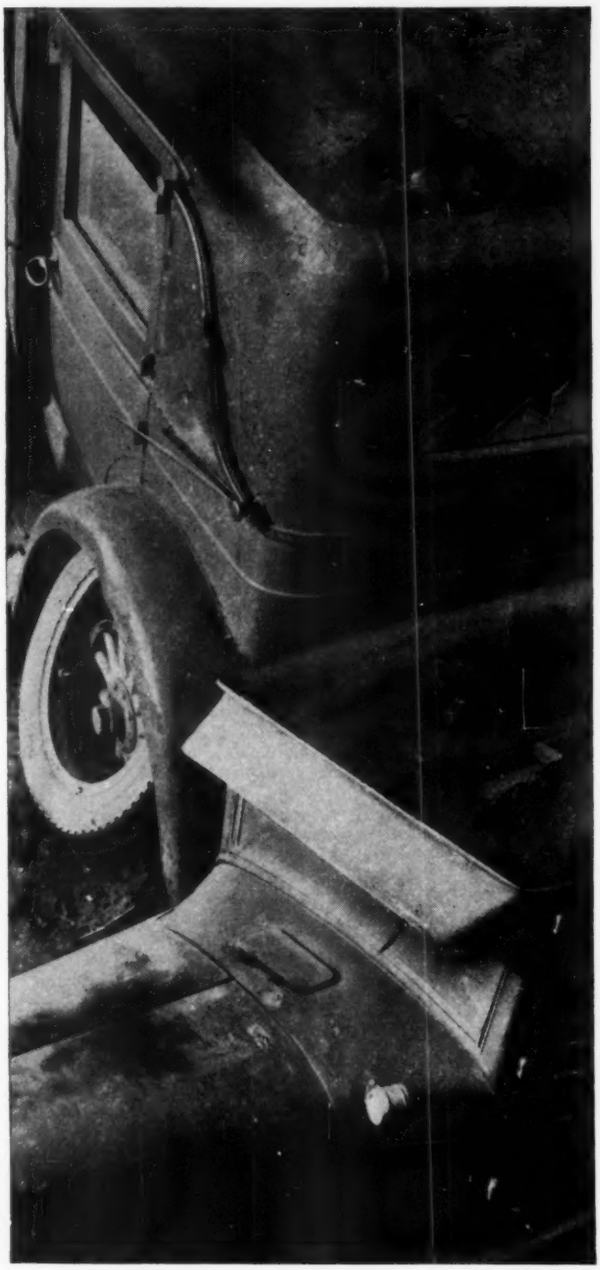
In a letter addressed to the Secretary of the Society, an applicant for this scholarship should set forth his qualifications (age, place of birth, education, experience, references, and photograph). Not less than six letters of reference addressed to the Secretary of the Society will be required from his former teachers and employers. The candidate should state particularly what training he has had in technical schools and elsewhere, either before or after graduation, in hydraulics, and in the German language. A statement by the candidate of the field of engineering in which he proposes to work is also requested. The last day for filing an application will be May 15, 1935.

U.E.T. Elects Officers

AT A MEETING of the United Engineering Trustees, Inc., on January 24, 1935, the following officers were elected: President, Harold V. Coes; first vice-president, G. L. Knight, second vice-president, H. G. Moulton; secretary, John Arms; treasurer, Clifford P. Hunt; assistant treasurer, Otis E. Hovey.

President Coes appointed the following committees: Finance Committee, G. L. Knight, chairman, Otis E. Hovey, H. G. Moulton, W. L. Batt, and H. V. Coes, ex officio; Real Estate Committee, H. R. Woodrow, chairman, John P. Hogan, A. L. J. Queneau, H. V. Coes, and the society secretaries, Messrs. Seabury, Parsons, Davies, and Henline.

(*Continued on page 202*)



Even Time, the Junkman

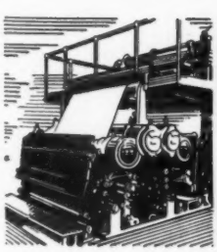
Respects Rubber

METAL rusted, wood rotted, fabric ruined—but the rubber window frames of these 10- and 20-year-old bodies are still flexible and soft.

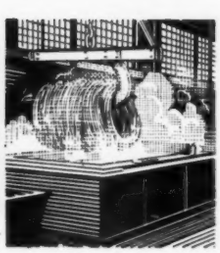
In these thrifty 'thirties, the product which adds durability adds buyers. Rubber, in its new compounds developed by Goodrich, is already multiplying durability for many a product, many a processing machine.

Goodrich developed much of the science of rubber compounds on which the entire rubber industry is based. And Goodrich has continued this development until today we can give you a rubber which will flex millions of times without distortion; a rubber which will resist chemicals, heat, oil, cold; a rubber which can be inseparably attached to metal; a rubber which will absorb vibration and so quiet machinery or protect delicate instruments; a rubber which can be made tasteless and odorless and in any color and any texture from that of human skin to shark skin.

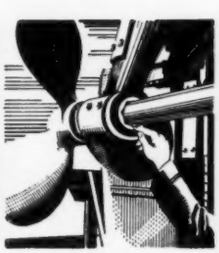
Rubber is on the march to increased use in industry—adding sales appeals, reducing costs, cutting waste. The B. F. Goodrich Co., Mechanical Rubber Goods Div., Akron, O.



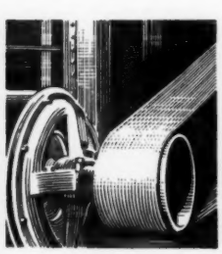
Newspaper printers' rollers had always been made of a glue-glycerine combination. Now a Goodrich rubber roller outwears the traditional product by years, also saves time and cost in printing.



Rubber can be compounded by Goodrich to give almost any combination of advantages. One Goodrich compound, for lining tanks, resists heat and corrosive acids, and may last 25 or 50 years—or even longer.

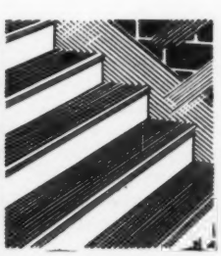


Marine propeller shaft bearings formerly were made of bronze or wood, but corroded, rotted, wore away. Now Goodrich makes a rubber bearing that serves 4 to 10 times as long as the finest wood or bronze.



Leather was thought necessary for long transmission belt life. Goodrich produced a rubber belt that in hundreds of industrial uses outlasts leather, yet shows a lower first cost and lower maintenance cost.

First requirement of a gas pipe line is that the joint must not leak. Goodrich coupling rubbers in local and long-distance lines have kept gas pipe joints tight for 50 years, without attention.



Goodrich compounded a rubber for stair treads that outwears stone or wood, is far safer in any weather or location, can be made in almost any attractive color desired.

Goodrich

ALL *products problems* IN RUBBER

Coming Meetings of A.S.M.E. Local Sections

Birmingham: March 28. Alabama Power Auditorium. Subject: The Results of Research in Feedwater Control, by E. W. Nick, President, Northern Equipment Company, Erie, Pa. This lecture will be illustrated.

Chicago: March 18. Engineering Building Auditorium at 7:30 p.m. Joint meeting with the Western Society of Engineers, American Foundrymen's Association. Subjects: Castings—Gray Iron, by H. Bornstein, Deere & Co., Moline, Ill.; Malleable Iron, by D. P. Forbes, Gunite Foundries Co., Rockford, Ill.; Steel, by A. N. Conarroe, National Mal. & Steel Castings Co., Chicago. Specimens of castings will be on exhibition at 6:30 p.m.

Cleveland: March 15. William L. Batt, Vice-President of the Society, will speak on "How the American Engineering Council Helps the Engineer."

Colorado: March 22. Parisienne Rotisserie, Denver, Colo., at 6:30 p.m. Subject: Balancing of Machinery—a Discussion of the Science of Balancing and Demonstration of Some Balancing Equipment, by Robert A. Hake, Engineer, General Electric Co., Denver, Colo., assisted by Robert F. Throne, Superintendent Steam Production, Public Service Company of Colorado, Denver, Colo.

Detroit: March 12. Joint Meeting with the Chrysler Engineers Club—Dinner at 6:30 p.m. Meeting at 8:00 p.m. at the Detroit Leland Hotel. Subject: Stress Concentration and Failure of Machine Parts, by Dr. Stephen Timoshenko, University of Michigan. There will also be a lecture on General Relationship Between Production and Engineering by a member of the staff of the Chrysler Corporation.

Florida: April 4–6. Miami, Fla. Joint meeting with the Florida Engineering Society.

Hartford: March 13. State Trade School at 8:00 p.m. Subject: Cemented Carbide Cutting Tools by Malcolm F. Judkins, Chief Engineer, Firthite Division, Firth-Sterling Steel Co. This will be a joint meeting with the American Society of Steel Treaters.

Mid-Continent: March 22. Tulsa Club Building at 7:15 p.m. Subjects: The Use of Electric Motors for Well Pumping, Economics of Electric Motors, by John T. Hayward, Barnsdall Oil Co.

Milwaukee: March 20. Wisconsin Club at 8:00 p.m. Subject: Stratosphere Balloons and Flights, by V. R. Jacobs, Sales Manager, Goodyear Zeppelin Corporation, Akron, Ohio.

New Haven: March 6. Peabody Museum, New Haven at 8:00 p.m. Prof. R. S. Lull will accompany the members of the New Haven Section through the Peabody Museum and explain the prehistoric and modern specimens of animal life on exhibition.

New Orleans: March 11. Joint Meeting with the Louisiana Engineering Society. H. G. Hiebeler of Houston, Texas, will be the principal speaker.

Ontario: March 14. Dunlap Observatory, Richmond Hill, Toronto, Ont., at 8:15 p.m. Subject: The Mechanical and Astronomical Details of the Observatory, by Professor Chant of the Dunlap Observatory.

Philadelphia: March 26. Engineers' Club of Philadelphia, 1317 Spruce St., Phialdelphia, Pa. Subject: Steel, by Thomas Nelson, Midvale Steel Co.

Rochester: March 21. Rooms of the Rochester Engineering Society. Subject: Lubrication by Horace F. Smith of the Eastman Kodak Co.

Schenectady: March 28. Union College at 8:00 p.m. Subject: Engineers' Council for Professional Development, by C. F. Hirshfeld, Detroit Edison Co., Detroit, Mich.

Ambrose Swasey Honored

AMBROSE SWASEY, past-president and honorary member, A.S.M.E., of the Warner and Swasey Co., Cleveland, Ohio, has been voted the Washington Award for 1935.

The Washington Award was founded in 1916 by John Watson Alvord, to be awarded annually by the Western Society of Engineers upon the recommendation of a commission composed of nine representatives of that society and two representatives of each of the four national engineering societies, the Am.Soc. C.E., A.I.M.E., A.S.M.E., and A.I.E.E. It is bestowed in recognition of devoted, unselfish, and preeminent service in advancing human progress through engineering.

On the occasion of his eighty-eighth birthday, Mr. Swasey received the unusual distinction of having an asteroid, discovered by Dr. Otto Struve, director of Yerkes Observatory, named "Swaseya" in his honor. Mr. Swasey's firm has been the builder of some of the world's greatest telescopes. The 40-in. refractor at the Yerkes Observatory, built by Warner and Swasey Co., is still the largest in the world.

Coming A.S.T.M. Meetings

A SYMPOSIUM on paint will be the technical feature of the 1935 A.S.T.M. Regional Meeting, Philadelphia, Pa., March 6, at the Warwick Hotel. Fourteen formal papers will be presented.

The A.S.T.M. Committee week, March 4 to 8, at the Warwick Hotel, will provide an opportunity to review the research and standardization work of many A.S.T.M. committees. It is expected that about 100 committee meetings will be held during the week.

It has been announced that the 38th Annual Meeting of the A.S.T.M. will be held at the Book-Cadillac Hotel, Detroit, Mich., June 24 to 28, inclusive.

Testing Method for Drying Equipment Proposed

A PROPOSED method for testing drying equipment has been prepared in tentative form by the Committee on Drying of the Process Industries Division of The American Society of Mechanical Engineers. Copies of the proposed method may be secured at the Society's headquarters. Discussion and criticism are solicited, and should be addressed to C. W. Thomas, Committee on Drying, Process Industries Division, A.S.M.E., 29 West 39th Street, New York, N. Y.

President Flanders to Visit A.S.M.E. Groups With Secretary Davies

VISITS to A.S.M.E. Local Sections and Student Branches in St. Louis, Kansas City, Nebraska, and Iowa will be made by Ralph E. Flanders, president of the Society, during the third week of March. C. E. Davies, secretary of the Society, will accompany Mr. Flanders, and will also visit other sections and branches in this region and in the East.

MR. FLANDERS' ITINERARY

March 18, St. Louis, and University of Washington
March 19, Kansas City, and University of Kansas
March 20, Nebraska, and University of Nebraska
March 21, Tri-Cities (Davenport, Iowa), and University of Iowa

MR. DAVIES' ITINERARY

March 18, St. Louis, and Missouri School of Mines, Rolla, Mo.
March 19, Kansas City, and University of Missouri, Columbia, Mo.
March 20, Nebraska, and University of Nebraska
March 21, Tri-Cities (Davenport, Iowa), and Iowa State College, Ames, Iowa
March 22, Minnesota Section
March 25, Chicago, and Armour Institute and Lewis Institute, Chicago, Ill.
March 26, St. Joseph Valley (South Bend, Ind.), and Notre Dame University
March 27, Peninsula (Grand Rapids, Mich.)
March 28, Detroit, and University of Detroit and University of Michigan
March 29, Toledo
April 1, Cleveland, and Case School of Applied Science
April 2, Erie
April 2, Buffalo
April 3, Ontario, and University of Toronto
April 4, Rochester
April 5, Syracuse
April 5, Utica

Vice-President O'Brien to Visit A.S.M.E. Groups in Southwest

WHILE making a business trip in the Southwest, during March, E. W. O'Brien, vice-president, A.S.M.E., and Editor, *Southern Power Journal*, will be willing to visit local sections and student branches. Mr. O'Brien's headquarters will be as follows:

February 25 and 26, Memphis, Tenn., Hotel Peabody
February 27, Little Rock, Ark.
February 28, Oklahoma City, Okla., Black Hotel
March 1 and 2, Oklahoma City and Tulsa, Okla., Tulsa Hotel
March 3 to 5, Dallas, Texas, Hotel Barker
March 6, San Antonio, Texas, Hotel Plaza
March 7 to 9, Houston, Texas, Hotel Plaza
March 10 to 12, New Orleans, La., Care James M. Todd, Balter Bldg.
March 13, Birmingham, Ala., Hotel Tutweiler

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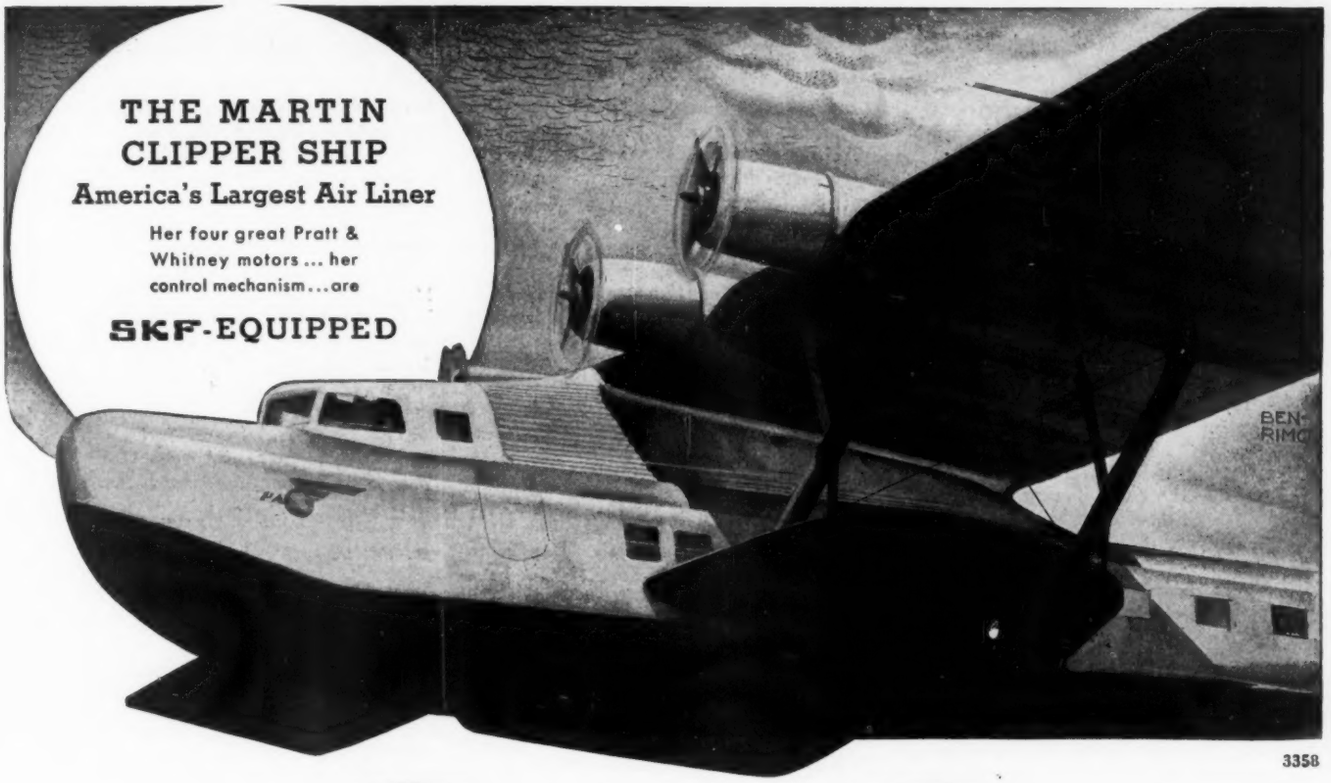
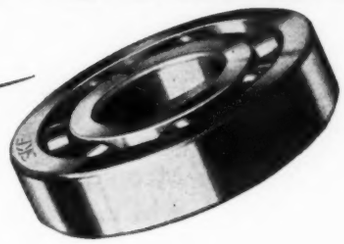


AWARD *for* PERFORMANCE



TRIED and true bearings, those that have been selected for the world's newest and greatest liner of the air. Tried on the Spirit of St. Louis . . . the Columbia . . . the America . . . the Question Mark . . . the Macon . . . the Graf Zeppelin. And so news that the great Martin Clipper Ship was to be SKF-equipped was welcomed not as just another order for bearings, but in view of SKF's record along the skyways, as another significant "Award for Performance". SKF Industries, Inc., Front Street and Erie Avenue, Philadelphia, Pa.

SKF
BALL AND ROLLER BEARINGS

This Month's Authors

GEORGE M. MURPHY is an instructor in chemistry at Columbia University. From 1930 until 1932 he was research assistant to Prof. Harold C. Urey, and during this time he was co-discoverer with Dr. Urey and Dr. F. G. Brickwedde of the heavy-hydrogen isotope discussed in his article. He holds a Bachelor of Science degree from the University of North Carolina and a Ph.D. degree from Yale University. His publications, besides the paper describing the discovery of deuterium, include other papers on heavy hydrogen and one on the relative abundance of the nitrogen isotopes.

I. N. Liphshitz, junior member, A.S.M.E., received the degree of B.S. in engineering from the College of the City of New York, School of Technology, in 1932, and the degree of M.E. in 1933 from the same institution. His interest in the history of science and technology has resulted in a series of three critical studies of which this paper is one.

H. Hencky, member, A.S.M.E., was formerly associate-professor of mechanics at the Massachusetts Institute of Technology. Mr. Hencky received the certificate of Civil Engineering from the Technical University of Munich (1908) and the degree of Doctor from the University of Darmstadt (1913). Before the war he spent a few years with the state railways in Alsace-Lothringen, in Strasbourg, and in Russia. At the outbreak of the war he was taken prisoner in Charkow and was interned in the Ural district. Later he was a lecturer for three years in the Universities of Darmstadt and of Dresden and for eight years with the University of Delft, Holland, in applied mechanics.

Franklin L. Everett is an instructor at the University of Michigan. In his present position he is interested particularly in engineering mechanics and in research work in strength of materials. He was formerly associated with the general engineering department of the Standard Oil Company of New Jersey on safety inspection.

Messrs. N. S. Osborne, H. F. Stimson, and D. C. Ginnings are known to readers of MECHANICAL ENGINEERING for the work done by them at the U. S. Bureau of Standards in connection with the researches under the auspices of the A.S.M.E. Special Research Committee on the Thermal Properties of Steam.

Dr. Frederick G. Keyes, with whom are associated at the Massachusetts Institute of Technology Messrs. L. B. Smith and H. T. Gerry, has been engaged on other phases of the steam research program at M.I.T.

C. R. Soderberg, member, A.S.M.E., is manager, turbine apparatus division, Westinghouse Electric and Manufacturing Company, South Philadelphia Works. After receiving his university education, Mr. Soderberg was graduated as naval architect from Chalmers' Institute of Technology, Goteborg, Sweden, in 1919. He received a fellowship from the American Scandinavian Foundation in 1919 for the study of shipbuilding in the United States, and spent 1919–1920 at M.I.T. and the University of Michigan. He was employed as draftsman by the New York Shipbuilding Corp. in 1921, and in 1922 by the Westinghouse Company, where he worked until 1928 on vibration and other dynamical problems connected with heavy traction railway equipment and large power machinery. After spending two years with the Swedish General Electric Company in the designing of large turbogenerators and turbines, he returned to the Westinghouse Company in East Pittsburgh, and was transferred to his present location in May, 1931.

William McClellan, member, A.S.M.E., and president, Potomac Electric Power Company, received the degrees of B.S. in 1900, Ph.D. in 1903, and E.E. in 1914, from the University of Pennsylvania. He was an instructor in physics at the University from 1900 to 1905, and also served with the Philadelphia Rapid Transit Co. at the same time. For the next two years he was associated with Westinghouse, Church, Kerr & Co.; and from 1907 to 1915, was a director of Campion McClellan Co. He was a member of the firm of Paine, McClellan, and Campion from 1915 to 1920; of McClellan and Junkersfeld from 1922 to 1929; vice-president of Stone and Webster from 1929 to 1933; and president of William McClellan & Co., Ltd., from 1930 to 1933. He was consulting engineer of the Public Service Commission, 2nd District, New York, from 1911 to 1913; dean of the Wharton School of the University of Pennsylvania from 1916 to 1919; vice-president of the Cleveland Electrical Illuminating Co. from 1919 to 1929; and member of the President's Commission on Muscle Shoals in 1925.

Theodore Hatch, instructor in industrial sanitation, Harvard Engineering School and Harvard School of Public Health, lectures on the engineering aspects of problems in industrial disease control. He has done considerable work in research on dust, its properties, production in industry, control; in the development of sampling instruments and methods of measuring dust concentrations and size of dust particles, in the study of exhaust hoods and air-cleaning equipment, and in the design of dust-control systems for granite cutting and the pulverizing, mining, and hard-rock industries.

Candidates for Membership in the A.S.M.E.

THE application of each of the candidates listed below is to be voted on after March 25, 1935, provided no objection thereto is made before that date, and provided satisfactory replies have been received from the required number of references. Any member having comments or objections should write to the secretary of the A.S.M.E. at once.

NEW APPLICATIONS

AARON, ROBERT H., San Francisco, Calif.
BACON, BENJAMIN S., Nutley, N. J.
BEESON, KENNETH H., Colton, Calif.
BRANDERS, HANS, Warkaus, Finland
DICKINSON, W. N., Rockville Center, L. I., N. Y. (Rt)
DIEFENBACH, JOHN S., Shelton, Conn.
FABEL, DONALD C., Cleveland, Ohio
FLEISCHMANN, WALTER L., Erie, Pa.
FREESE, C. E., Youngstown, Ohio
GLENN, GRAEFF W., Philadelphia, Pa.
JOHNSON, JAMES F., Belleville, N. J.
KARPOV, A. V., Pittsburgh, Pa.
LAWRENCE, EARL W., Charlotte, N. C.
LIPPINCOTT, W. RICHARD, New York, N. Y. (Re)
MAULBETSCH, JOHN L., Ann Arbor, Mich.
PINSAN, PHILIP E., Union City, N. J. (Re)
SMITH, E. DILLON, New York, N. Y.
STEWART, W. FRED, Tulsa, Okla.
SULLIVAN, SYLVESTER J., Rosedale, L. I., N. Y.
TRESILIAN, STEWART S., Derby, England
WALKER, WILLIAM K., New York, N. Y.
WEISMANN, VICTOR, Los Angeles, Calif.
WORTHINGTON, JOHN A., Ruxton, Md.

CHANGE OF GRADING

Transfers from Associate-Member

BLAIR, ERNEST L., Wollaston, Mass.
MOTHERAL, HARRY H., Arlington, N. J.

Transfers from Junior

BENEDICT, OTIS, Jr., Brooklyn, N. Y.
BLAKE, THOMAS W., Green Bay, Wis.
GRIESENBECK WILHELM, Schwelm, Westf., Germany
GULLIKSON, A. C., Stanford University, Calif.
HANSON, L. C., Hopewell, Va.
JARCHO, RALPH, Brooklyn, N. Y.
KENNEY, JAMES T., Antioch, Calif.
MCSWEENEY, WILLIAM T., Colombia, S. A.
SMITH, HARRY NEWTON, Millburn, N. J.
THOMPSON, W. G., Los Angeles, Calif.

Recent Deaths

ANGUS, ROBERT, January 16, 1935
BLACK, LEE JACKSON, August 10, 1934
BLAINE, JOSEPH R., December 17, 1933
COADY, FRANK J., 1934
HALL, DWIGHT K., December 25, 1934
HERSEY, AARON S., January 15, 1935
HERZOG, LOUIS, December, 1934
HESS, FRANK J., December 23, 1934
JACKSON, W. W., January 2, 1935
MCGEORGE, JOHN, February 27, 1933
MILLER, HAROLD R., March 31, 1934
MITCHELL, ROBERT L., JR., December 28, 1934
MOODY, WILLIAM O., December 25, 1934
OTTIS, FRANCIS J., January 5, 1935
PARSONS, H. DEB., January 26, 1935
ROSS, CHARLES E., January 11, 1935
SANDERSON, EDWIN J., December 26, 1934
THOMAS, CARROLL D., December 24, 1934

A.S.M.E. Transactions for February, 1935

THE February, 1935, issue of the Transactions of the A.S.M.E. contains the following papers:

Ten Years of Stoker Development at Hudson Avenue (FSP-57-3), by John M. Driscoll and W. H. Sperr (Discussion will be received on this paper until April 10, 1935)

Use of Current Meters for Precise Measurement of Flow (HYD-57-1), by Floyd A. Nagler

Report on Oil-Engine Power Cost for 1933 (OGP-57-1)